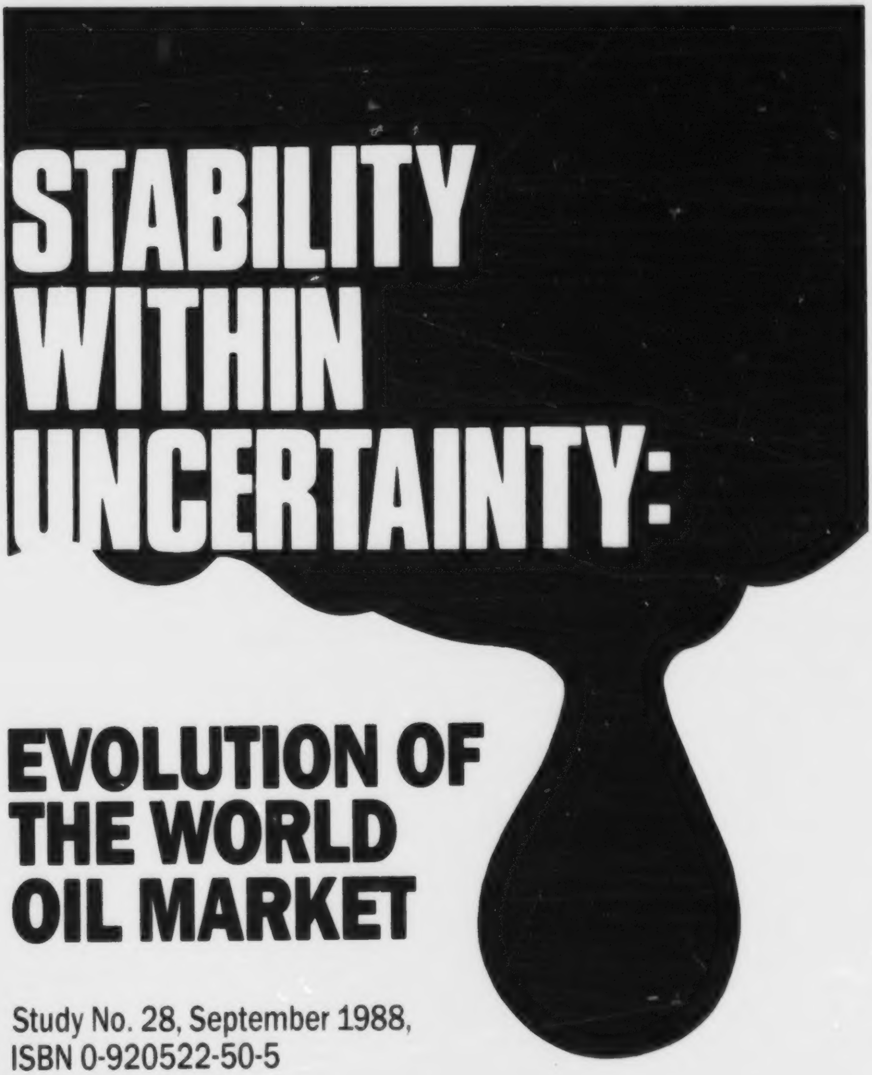

STABILITY WITHIN UNCERTAINTY:

EVOLUTION OF THE WORLD OIL MARKET

Study No. 28, September 1988,
ISBN 0-920522-50-5

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ENERGY
RESEARCH
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89-02718/

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ISBN-0-920522-50-5

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September 1988
Printed in Canada
Price: $55.00
(when ordering please add 15% for
postage and handling)

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Preface

This study was initiated in the fall of 1986 and completed in July 1988. The data assembly and modelling work was completed during the period November 1986 to April 1987. A separate Executive Summary covering the important results and conclusions of the study is also available from the Institute.

The study was undertaken at the request of the CERI Board of Directors in order to better clarify the forces underlying the highly volatile world oil market. The analytical framework, data and final results were reviewed by a Technical Advisory Committee composed of officials from the following organizations; the U.S. Department of Energy, Massachusetts Institute of Technology, Conoco Inc., British Petroleum PLC, Kernforschungsanlage (KFA: West Germany) and the International Energy Agency. The data used to represent the various non-OPEC producing countries was vetted through private sector sponsors of the Institute, operating in the various countries included in the study. The authors extend their thanks for the interest and support provided by these individuals.

The authors also express their thanks and that of the Institute to the six-member Advisory Committee of Canadian industry and government representatives for the direction, insights and constructive criticism provided for this study. The views and conclusions expressed herein are, however, those of the authors, who accept sole responsibility for any errors or omissions that may exist.

Special thanks must be extended to various members of the Institute's staff for their efforts in compiling the finished study. Graphics work was performed by Vance Lickiss and the final manuscript and previous drafts and interim reports were processed by Janice Morrison and Michele Irvin. Finally, Dr. Gerry Angevine and Morgan MacRae provided support and guidance through the project.

> This report is the beginning of a body of research which the Institute believes will assist the Canadian energy sector in better understanding the forces underlying the evolution of the world oil market. The refinements anticipated for the analytical framework, combined with the increasing quality of oil market expertise housed within the Canadian Energy Research Institute, will make these annual reports on the world oil market an important and valuable contribution to the understanding of energy issues in Canada.

EXECUTIVE SUMMARY

Introduction

In the fall on 1986, the Board of Directors of the Canadian Energy Research Institute instructed CERI staff to undertake a detailed analysis of the fundamentals of, and medium- to long-term outlook for, the world oil market. The objective of the exercise was to develop a methodology for analyzing alternative assumptions and scenarios regarding the future path of the world oil market and crude oil prices, to aid Institute sponsors in medium- and long-term corporate planning and energy policy development. The framework for analysis was to be sufficiently detailed, comprehensive and disaggregate to allow examination of, among others, the following question: In the event of a complete collapse of the OPEC cartel and the development of a "competitive" world oil market structure, what would be the most-likely path for crude oil prices, in what countries or regions of the producing world would output be affected, and to what extent?

The ability to properly analyze such potential market developments requires the capture of demand response to price and income changes, the cataloguing of established and potential reserves in producing regions around the world, an accurate representation of capital and operating costs, drilling activity and success rates in the various regions, and numerous other technical and economic relationships underlying the discovery, production and consumption of crude oil. To accurately represent these relationships requires, in turn, the development of an analytical framework able to accommodate large volumes of detailed information at the individual country level.

In studies such as this, the quality of information underlying the analysis is critical to the accuracy and reasonableness of the final results. To aid in this exercise, the Institute brought together an Advisory Committee of Canadian experts in oil market operations and analysis, drawn from both the private and public sectors, and a Technical Advisory Committee, composed of recognized experts in world oil market modelling and analysis, to comment on the methodology, data, and final draft of the study. To further ensure that our representation of world oil market supply and demand was as accurate as possible, the inputs used to represent key market factors (e.g., established reserves, ultimate potential reserves) were vetted not only through the Committee members but also through companies operating in the various regions of the world represented in this study.

The end result of these efforts is an analytical tool of tremendous value, flexible enough to accommodate analysis of a wide range of policy options and alternative scenarios, and sufficiently detailed to generate important insights regarding the linkages and interrelationships underlying the operations and evolution of the world oil market. Combining this powerful analytical tool with the energy market expertise housed within the Canadian Energy Research Institute has resulted in this, the first in a series of reports to be produced by CERI on the operations of, and outlook for, the world crude oil market.

It is fairly safe to say that the market projections summarized below will not prove to be accurate; no analytical framework can account for the timing and magnitude of changes to the key factors determining market price, nor can an analyst accurately predict the timing and magnitude of political or social upheaval, or of changes to energy policy. **However, as we have seen in the past, it is the fundamental characteristics underlying the supply and demand side of any market, which will ultimately determine the direction and development of that market.**

Energy planning and energy policy must be formulated in recognition of these medium- and long-term considerations, in addition to near-term constraints and opportunities. This study provides a clearer understanding of the future evolution of the world oil market and, by so doing, will aid in the development of rational and realistic domestic energy planning, policy and development.

Summary of Results

"Volatility" is a catchword that has become all too familiar to world oil market analysts over the last 3 years. World oil prices refuse to follow a stable pattern, and price swings of more than $1.00 per barrel during a day have become commonplace. Effective planning and capital allocation within such an uncertain environment requires that industry planners have a sound grasp of a price track that is most likely to occur in the future, and in which direction prices are likely to move given plausible divergences from the assumptions which underlie this price track.

The reference crude oil market scenario described below reflects the combined judgement of the study authors as to the most likely path for crude oil prices, given a rational and well-behaved market and the absence of unforeseeable supply and demand shocks. The term "reference" was chosen because the scenario embodies a very reasonable set of assumptions regarding production levels for the Organization of Petroleum Exporting Countries (OPEC) over time, non-OPEC supply potential, GDP growth rates around the world (described in Appendix C), and the responsiveness of oil demand to changes in price and GDP growth rates (described in Appendix B). The price and volume projections reported below represent the annual average "market-clearing" levels resulting from these assumptions.

The level of OPEC production assumed for the reference scenario is provided in Table 1. OPEC production is assumed to average 18.8 million barrels per day (MMb/d) in 1988. Between 1989 and 1991 the ability, and desire, of the cartel to increase production is assumed to be mitigated by increases in non-OPEC production. During this period, the cartel's average annual daily output is assumed to grow by less than 2.0 percent per annum. After 1991, the ability of OPEC to take advantage of world oil demand growth and stagnant non-OPEC output allows OPEC production to increase at an average annual rate of roughly 3.5 percent per annum. OPEC production in the year 2000 reaches 27.4 MMb/d, a level that is 46 percent higher than current levels but significantly below the cartel's current productive capacity of 34 MMb/d.

The reference scenario results are summarized in Table 2. Remembering that these results are conditional on the assumed level of OPEC production, the price trajectory shown in the table represents a readily sustainable path. The principal trend is for slowly rising prices through to the mid-1990s, followed by slightly accelerated price increases (averaging 3.7 percent per year) over the remaining years of the forecast horizon. Prices reach $22.50 (U.S.) per barrel by 1995 and $26.90 per barrel by the year 2000. (Note that all prices are in constant $1987 U.S., for West Texas Intermediate crude at Cushing, Oklahoma. Transportation and quality adjustments will yield equivalent prices for alternative crudes in various regions of the world).

The near-term growth in crude oil prices is made possible by increased levels of world oil consumption over the next 3 years, triggered largely by the steady fall in prices over the period 1982-1987. Oil consumption outside the centrally planned economies (CPEs) is projected to increase by more than 1.0 MMb/d between 1987 and 1990. Rising real oil prices dampen the rate of growth in consumption to less than 1.0 percent per annum through the mid-1990s. From 1995 to the end of the century, growth in oil consumption is expected to strengthen slightly to about 1.1 percent per annum as the dampening effects of rising oil prices are more than offset by continued economic growth. Non-CPE oil consumption is projected to reach 54.4 MMb/d by the year 2000.

Projections of total world oil consumption by refined product are shown in Table 3. Gasoline exhibits the strongest demand growth of the

TABLE 1

REFERENCE CASE OPEC PRODUCTION
1987-2000

Year	Annual Daily Average (MMb/d)	Annual Change (%)
1987	17.7	-1.1
1988	18.8	6.2
1989	19.3	2.7
1990	19.5	0.8
1991	19.8	1.8
1992	20.4	3.0
1993	21.3	4.4
1994	22.0	3.3
1995	22.8	3.6
1996	23.6	3.5
1997	24.4	3.4
1998	25.4	4.1
1999	26.4	3.9
2000	27.4	3.8

SOURCE: Canadian Energy Research Institute.

TABLE 2

REFERENCE CASE MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S.)	World Demand (MMb/d)	World Supply (MMb/d)	Non-CPE Demand (MMb/d)	Non-CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.63	62.12	61.54	48.67	45.85	2.24
1988	17.50	63.26	62.97	49.62	47.16	2.17
1989	18.54	64.00	64.00	50.19	47.99	2.20
1990	19.40	64.59	64.58	50.59	48.36	2.22
1991	19.82	65.23	65.23	51.04	48.92	2.12
1992	20.69	65.80	65.79	51.40	49.59	1.81
1993	21.06	66.44	66.48	51.85	50.39	1.50
1994	21.78	67.06	67.05	52.24	50.93	1.30
1995	22.53	67.70	67.69	52.63	51.53	1.10
1996	23.65	68.25	68.25	52.94	52.04	0.90
1997	24.69	68.78	68.78	53.23	52.54	0.70
1998	24.99	69.47	69.47	53.69	53.19	0.50
1999	26.15	70.10	70.14	54.08	53.87	0.25
2000	26.90	70.78	70.77	54.52	54.51	0.00

SOURCE: Canadian Energy Research Institute.

TABLE 3

WORLD OIL DEMAND BY PRODUCT
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,393	20,216	11,817	13,697	62,124
1988	16,762	20,586	12,088	13,823	63,260
1989	17,064	20,797	12,196	13,945	64,003
1990	17,335	20,935	12,235	14,083	64,589
1991	17,619	21,084	12,280	14,251	65,232
1992	17,888	21,191	12,290	14,431	65,798
1993	18,164	21,324	12,326	14,627	66,440
1994	18,430	21,442	12,353	14,831	67,057
1995	18,704	21,558	12,381	15,051	67,695
1996	18,967	21,633	12,378	15,275	68,254
1997	19,222	21,690	12,364	15,502	68,777
1998	19,506	21,813	12,405	15,750	69,474
1999	19,779	21,901	12,419	16,001	70,100
2000	20,063	22,009	12,450	16,260	70,780

SOURCE: Canadian Energy Research Institute.

refined products, averaging about 1.6 percent per annum over the forecast horizon. This is largely due to a lack of viable alternative fuels and to a lower rate of price increase than the other products, since a given increase in the crude oil price translates into a smaller end-use price increase for gasoline due to the larger share of end-use price attributable to taxes and refining costs. Heavy fuel oil consumption is projected to be essentially flat over the forecast period, consistent with the trend towards a "lighter" demand barrel.

On a regional basis (see Table 4), the less developed countries (LDCs) and OPEC contribute the largest share to world demand growth, with consumption increasing at an average annual rate of 2.0 and 2.5 percent, respectively. Consumption in the CPEs is also projected to grow quite vigorously, at an average rate of 1.6 percent per annum. A more modest growth rate of 0.6 percent per annum is expected in the Organization for Economic Co-operation and Development (OECD) countries, led by the U.S. with its burgeoning gasoline consumption. Of the 8.0 MMb/d increase in world oil consumption projected to occur by the year 2000, OPEC and the LDCs contribute 1.4 and 2.8 MMb/d respectively, the CPEs contribute another 3.0 MMb/d, while the combined OECD countries add only 2.0 MMb/d. Appendix E provides detailed demand projections, by product, for each of the seven demand regions defined in the study.

A summary of the reference scenario projections for world crude oil and NGL production is provided in Table 5. Projections for non-OPEC countries (excluding CPEs) are based on the assumption that they produce at productive capacity unless the price falls below operating cost, which it does not in this case. Combined crude oil output in these countries is projected to average 23.0 MMb/d in 1988, crest at 23.7 MMb/d in 1992, and decline to 21.3 MMb/d by the end of the forecast period. Total NGL production outside of OPEC is assumed to remain essentially flat, falling only slightly from 2.8 MMb/d to 2.7 MMb/d between 1988 and 2000.

Section 3.5.1.1 contains a detailed country-by-country breakdown of these supply projections. Appendix E provides country-specific information on projected drilling activity, finding rates, reserves additions and production.

In our view, this reference scenario and the associated price projections provide a very realistic picture of future world oil market developments. The level of crude oil production assumed for OPEC does not require that the cartel reduce quotas from current levels in the near term and should be attainable with a reasonable degree of cartel unity. Although prices increase quite modestly over the forecast period, steady demand growth and an eventual decline

TABLE 4

WORLD OIL DEMAND BY REGION
1987-2000
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECD	Less Developed Countries	OPEC	Central Planned Economies	Total World
1987	1,500	16,532	12,198	5,066	9,628	3,744	13,455	62,124
1988	1,505	16,878	12,423	5,118	9,876	3,816	13,644	63,260
1989	1,503	17,061	12,516	5,141	10,091	3,879	13,811	64,003
1990	1,503	17,156	12,538	5,155	10,288	3,947	14,002	64,589
1991	1,505	17,272	12,560	5,178	10,497	4,028	14,193	65,232
1992	1,507	17,349	12,543	5,197	10,690	4,118	14,394	65,798
1993	1,513	17,440	12,549	5,225	10,897	4,221	14,595	66,440
1994	1,517	17,504	12,538	5,244	11,103	4,331	14,820	67,057
1995	1,524	17,572	12,520	5,261	11,304	4,450	15,065	67,695
1996	1,529	17,620	12,473	5,265	11,484	4,572	15,311	68,254
1997	1,532	17,662	12,416	5,271	11,655	4,699	15,544	68,777
1998	1,541	17,757	12,406	5,297	11,855	4,838	15,780	69,474
1999	1,548	17,828	12,368	5,315	12,038	4,981	16,021	70,100
2000	1,559	17,916	13,343	5,339	12,231	5,132	16,260	70,780

SOURCE: Canadian Energy Research Institute.

TABLE 5

WORLD CRUDE OIL PRODUCTION SUMMARY
1987-2000
(Mb/d)

Year	Total	OPEC		CPE	Non-OPEC		Total Non-OPEC Liquids Production
		Crude Oil	NGLs		Crude Oil	NGLs	
1987	61,540	17,700	1,408	15,695	22,825	2,811	25,636
1988	62,969	18,800	1,443	15,810	23,017	2,798	25,815
1989	63,996	19,300	1,479	16,010	23,321	2,785	26,107
1990	64,581	19,450	1,516	16,220	23,520	2,774	26,295
1991	65,225	19,800	1,554	16,310	23,696	2,764	26,461
1992	65,790	20,400	1,593	16,200	23,741	2,755	26,496
1993	66,478	21,300	1,633	16,090	23,607	2,747	26,354
1994	67,049	22,000	1,675	16,120	23,413	2,740	26,153
1995	67,686	22,800	1,718	16,160	23,174	2,733	25,908
1996	68,245	23,600	1,762	16,210	22,844	2,728	25,573
1997	68,783	24,400	1,807	16,240	22,511	2,723	25,235
1998	69,466	25,400	1,854	16,280	22,110	2,720	24,831
1999	70,143	26,400	1,903	16,270	21,753	2,717	24,470
2000	70,771	27,400	1,952	16,260	21,341	2,716	24,058

SOURCE: Canadian Energy Research Institute.

in non-OPEC production will allow the cartel to gradually increase both its market share and annual revenue. In summary, the reference scenario is dependent on a rational and patient OPEC, willing to establish and abide by reasonable production quotas.

One of the principal challenges facing energy planners and policy makers is to anticipate the direction and timing of market shocks, and to gauge the magnitude of market response to these disruptions. The CERI World Oil Market model provides a most useful framework for analyzing various shocks to the market. The main report discusses six plausible alternative scenarios, summarized in Table 6. We will report here on only two of these, the High Resource Scenario and the Competitive Market Scenario.

The High Resource Scenario is predicated on the surprising resilience of non-OPEC production in the face of declining crude oil prices over the last 5 years, and the consistent upward revision of estimates of ultimate recoverable resources in the non-OPEC regions. In this scenario, we set estimates of ultimate crude oil reserves potential at the optimistic (5 percent probability) level. The result is to increase projected finding rates in each region, and hence productive capacity, over the forecast horizon.

The impact on the projected price path is shown in Figure 1. With OPEC production held at the same levels as in the reference scenario, the increase in non-OPEC production generates a significantly lower price path than in the reference scenario. Prices fall over 7 percent in 1988 to $16.80 per barrel, recovering to $22.40 per barrel by the year 2000, some 20 percent lower than under the reference case.

In our view, the High Resource Scenario provides a very legitimate low price projection, and we accord it virtually equal probability of occurrence as the reference scenario. Given the extent to which non-OPEC production has increased over the last decade, OPEC is rightfully fearful of such a scenario unfolding. However, as discussed further in the main report, OPEC would be better off in revenue terms under this low price scenario than under a scenario in which the cartel deliberately acted to discourage further development of non-OPEC productive capacity.

The Competitive Market Scenario is an attempt to arrive at a reasonable price floor for crude oil and to investigate the evolution of a noncartelized oil market. The scenario is based on a breakdown of OPEC in 1989. The countries currently in OPEC are assumed to return to previous productive capacity over the ensuing 3 to 4 years, yielding combined production in 1993 of some 33.4 MMb/d. In subsequent years, an additional 1.0 MMb/d of capacity is brought on stream each year--three quarters of this in

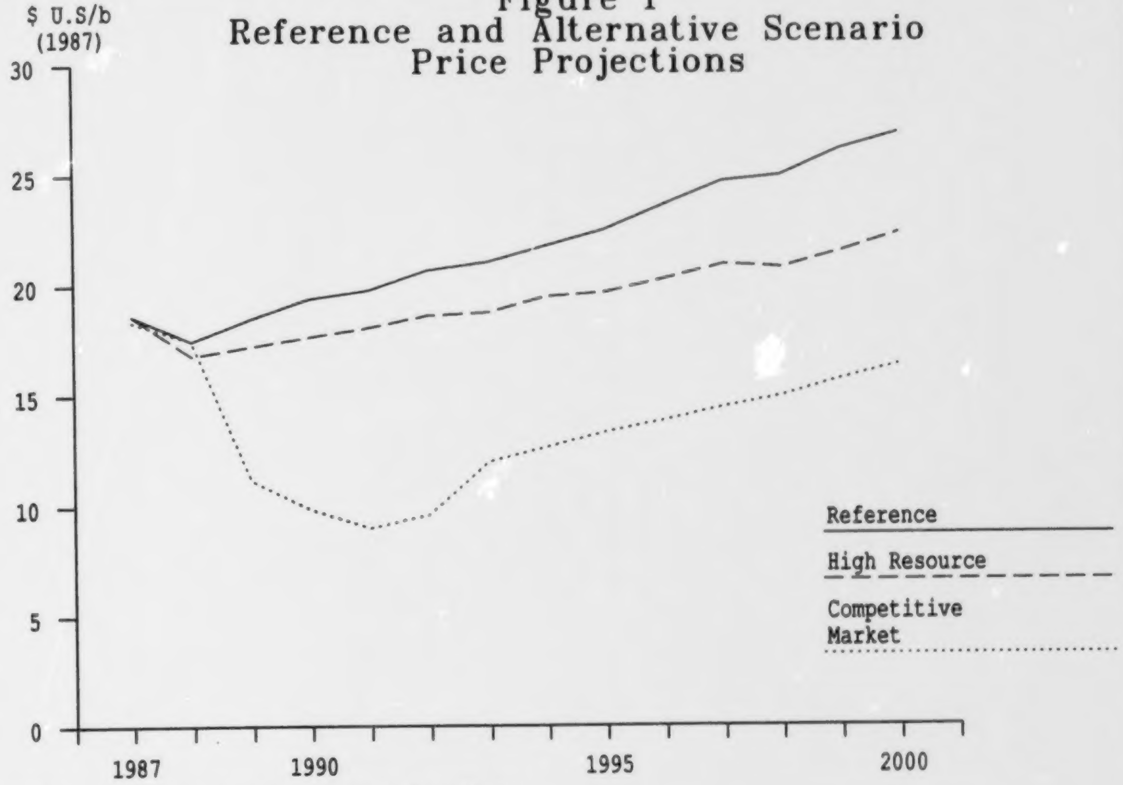
TABLE 6

ALTERNATIVE MARKET SCENARIOS

Scenario Title	Scenario Description
Competitive Market Scenario	Dissolution of OPEC in 1989, followed by a gradual return of all OPEC countries to previous peak output levels (complete by 1993) and a 1 MMb/d addition to combined capacity per year to the year 2000.
"GOPEC" Scenario	Dissolution of OPEC in 1989, with a new, four-nation mini-cartel (Saudi Arabia, Kuwait, Qatar and the U.A.E.) restraining production to maintain prices at $15 (U.S.) per barrel, in constant 1987 dollars.
OPEC Market Manipulation Scenario	OPEC manipulates production quotas to generate a series of price spikes (up and down) to maximize cartel revenue while deterring further development of non-OPEC conventional and nonconventional crude oil resources.
High Resource Scenario	Higher ultimate potential reserves estimate (5 percent probability level) assumed for all non-OPEC producing nations.
U.S. Import Fee Scenario	Domestic U.S. crude oil price set at a floor of $25 per barrel ($1987 U.S.) effective in 1989; all crude produced in, or imported into, the U.S. is priced at a flat $25 per barrel until the world price exceeds this floor price.
Alternative Economic Growth Scenario	Economic growth in the OECD countries set equal to zero in 1989 and 1990, reference case levels thereafter; economic growth in the LDCs set at 5.0 percent (versus 3.5 percent in the reference case) for the period 1990-2000.
High CPE Net Exports Scenario	Chinese net crude oil exports decline to zero by 1992, but Soviet net exports are maintained at their current level of 1.7 MMb/d through the forecast period.

SOURCE: Canadian Energy Research Institute.

Figure 1
Reference and Alternative Scenario
Price Projections



SOURCE: Canadian Energy Research Institute.

the reserves-rich Persian Gulf nations of Saudi Arabia, Kuwait, Qatar and the U.A.E., and the remainder in the other OPEC countries.

The impact of this series of events on the world oil price is dramatic (see Figure 1). The real world price of oil quickly falls to an average of just over $11.00 per barrel in 1989, with a further decline to $9.00 per barrel by 1991. In 1993, after four consecutive years of very low oil prices, a huge surge in world oil consumption becomes the dominant feature of world oil trade, and prices begin to slowly recover. Prices rebound to $12.00 per barrel in 1993 and reach $16.00 per barrel by the end of the century. World oil consumption reaches an astounding 80 MMb/d by the year 2000.

Dramatic as these developments are, our estimate of the competitive floor to world oil prices--about $9.00 per barrel in constant 1987 dollars--is somewhat higher than other estimates. This result is critically dependent on the speed of development of the massive Middle East reserves, relative to the price-induced surge in global oil consumption. If the OPEC taps could be opened more quickly, then the floor price could well prove to be lower. Indeed, one would expect downward price spikes, of short duration, to fall below $9 per barrel, due to market over-reaction to the collapse of the cartel. However, the re-establishment of a gradual, upward trajectory for crude oil prices would still occur. This is the basic stability within uncertainty which results from the fundamental supply and demand characteristics underlying the world oil market.

Stability Within Uncertainty:
Messages for the Canadian Energy Sector

The central finding of our research is that, despite the short-term volatility of the world oil market and the uncertainty inherent in a market structure dominated by a heterogeneous and fractious cartel, the market is fundamentally robust. Regardless of the severity of supply and demand side shocks placed on the market, the strength of the supply and demand fundamentals return the market to a stable, upward real price path. The artificial nature of the market-clearing (or equilibrium) price, resulting from the critical role of OPEC production in determining the level of the price, suggests that the market will not restabilize at a single price level after the impact of the shock has worked through the market. However, in all cases examined, including dissolution of the OPEC cartel, the world oil market returns to a stable, upward real price path. **Therefore, our key message to oil industry analysts, producers, consumers and policy makers is that the world oil market will respond to market uncertainties over the short-term, but follow a stable growth path over the long term.** In concert with the firming of crude prices will be a strengthening of the OPEC cartel, likely to be centered increasingly around the member countries in the Persian Gulf region. The gradual rise in crude oil price is predicated on steady growth in crude oil demand (particularly in the OPEC nations and the less developed countries), the inexorable decline in non-OPEC production (and U.S. production in particular), and a reasonable degree of cohesive market behavior on the part of the OPEC cartel. This message is premised entirely on the strength of the fundamental supply and demand characteristics underlying the oil market.

Given the above, our second message is that those involved in the oil market should focus their attention more on the fundamentals of the market, and less on the short-term fluctuations and volatility characteristic of the world oil market.

Our third key message is that virtually all of the short-term price risk associated with the world oil market resides on the downside. Over the forecast horizon for this study, extending to the year 2000, the study authors were unable to develop a single plausible, rational market scenario that resulted in a crude oil price path above that of our reference case scenario. In this regard, the reference case scenario represents a "best-case" scenario for crude oil producers, and for the OPEC member nations. This resistance to significantly higher prices to the end of the century is based on strong, negative demand response to higher prices, and the ability of non-OPEC producers to increase productive capacity in response to higher prices. On this last point, we would reiterate that we ascribe an almost equal probability to the price path resulting from the High Resource Scenario (see Section 4.4.3 and Appendix F3) as we do to the more optimistic price path associated with our reference case.

These key results--gradually strengthening real crude oil prices and the presence of considerable downside risk--and the forces underlying this market scenario provide a number of important messages for the Canadian energy sector.

Canadian Energy Consumers

Canadians enjoy virtually unparalleled access to energy, both in terms of quantity of energy resources and choice among energy types. With the exception of the Atlantic region and the Territories (where crude oil products remain the primary source of fuel due to the lack of natural gas transportation infrastructure and, in the latter case, absence of a developed electric power grid), Canadian energy consumers can choose among plentiful supplies of oil, natural gas, coal and electricity to meet their energy requirements. Despite the artificially low crude oil prices of the 1970s, Canadian energy consumers have gone a long way in reducing their reliance on refined petroleum products, largely through energy conservation and energy efficiency measures. Refined petroleum product consumption as a share of total end-use energy consumption has declined from some 55 percent in the mid-1970s to 40 percent in 1987.

Despite these impressive gains in off-oil energy consumption, certain regions and sectors in Canada are still critically affected by changes in crude oil prices. The Yukon and Northwest Territories and the Atlantic provinces remain heavily reliant on crude oil products and in the latter case, on crude oil imports. The transportation sector, particularly important to Canada with our small population spread across enormous distances, relies almost exclusively on crude oil products and will likely do so for the foreseeable future. Therefore, likely developments in the world oil market are of great importance to Canadian energy consumers, as are the messages to be gleaned from the likely evolution of that market.

The first message for energy consumers in Canada is that instability in crude oil prices, and hence in relative energy prices, is likely to be greater over the period to 1995 than later in the forecast horizon. Declining non-OPEC production, rising demand and gradually increasing OPEC production and market share should all serve to strengthen OPEC unity, and its grip on the world oil market, by the end of the 1990s. Therefore, it may be in the interest of energy consumers to invest in dual-fuel energy technologies in order to take advantage of relative price changes in the near and medium term.

Second, it appears that security of crude oil supply will be a minor concern over the next decade. This reflects the excess supply situation in the market and the ability of non-OPEC countries to maintain production levels, rather than the stability of OPEC. Short-term supply disruptions are adequately accommodated within the International Energy Agency emergency distribution agreement (of which Canada is a signator) and proper management of industry stockpiles.

Over the longer term, the importance of energy flexibility will likely decline as relative energy prices stabilize in response to renewed OPEC control over the world oil market. If available, energy consumers would be prudent in locking their energy requirements into long-term natural gas contracts, perhaps as early as the mid-1990s. It is highly likely that, beyond that point, crude oil price increases will exceed those of both the increasingly competitive natural gas market and the electricity market.

Canadian Oil Producers

Canada is a relatively small player on the world oil stage, accounting for under 3 percent of annual world production and possessing less than 1 percent of world proved oil reserves. However, the revenue, jobs, investment and economic growth generated by the roughly 500 million barrels per year of crude oil liquids production is important to the national economy, and of critical importance to the producing provinces of Western Canada and those affected by the emerging eastern and northern offshore basins.

Canada possesses established conventional crude oil reserves of 11.8 billion barrels, yielding a reserves life index in the order of 12 years. This is down considerably from the 30-year reserves life index for 1960, reflecting the inability of Canadian producers to replace production with new discoveries in the conventional areas. Canada also possesses tremendous reserves of nonconventional crude oil, located in the northern frontier, offshore of Atlantic Canada, and in the famous oil sands and bitumen deposits in Western Canada. Recent estimates suggest that some 1.7 trillion barrels of crude oil are contained in these bitumen deposits alone; however, it is estimated that only some 33 billion barrels are recoverable under current technology from surface mining operations, and another 33 billion from in situ operations (the latter yielding a very heavy crude that requires on-site upgrading or mixing with a diluent/light oil for transportation).

Therefore, despite our enormous ultimate potential crude oil resources, Canada faces a strategic and growing shortage in light and medium crude oil. This shortage lies behind the ongoing discussions aimed at expanding our heavy oil upgrading capacity in Western Canada, and the recent decision by the federal and Newfoundland governments to financially support the accelerated development of the Hibernia oil field, located some 300 kilometres off the coast of Atlantic Canada. Serious discussions are currently underway concerning a similar acceleration of northern frontier development and the expansion of Canada's integrated mined oil sands capacity.

These projects are extremely sensitive to forecasts of crude oil prices. While government assistance can reduce the risk and uncertainty associated with nonconventional crude oil development, it takes considerable fortitude to commit a company's financial resources to a project which will produce crude oil at a supply price some five times the cost of incremental crude oil production in the Persian Gulf region. Corporate executives and energy advisors will be critically judged on their success (or failure) in accurately assessing the direction and magnitude of future changes in crude oil prices.

The principal message for energy producers arising from this study is to focus strategic and corporate planning initiatives firmly on market fundamentals. The machinations of OPEC over the next 2 to 3 years, and the exaggerated, speculative market response which will accompany them, will tempt corporate planners and senior executives to place undue emphasis on short-term developments in crude oil pricing. However, the analysis undertaken for this study shows the world oil market to be surprisingly robust, even in the face of significant supply and demand shocks. Exploration and development plans based on a projection of gradually rising real crude oil prices to the end of the century will serve corporate strategists well.

Second, planners should recognize the downside price risk exposed in our sensitivity analyses and incorporate this into their strategic planning exercises. As we have shown above, while it is possible for circumstances to arise which would drive the crude oil price to below $10 (U.S.) per barrel, it is highly unlikely that such low prices would be sustained for any length of time. Even a complete collapse of the cartel and the accompanying surge in production will only delay, not eliminate, the projected rise in real crude oil prices. Our analysis would suggest a downside project risk assessment based on $12 (U.S.) per barrel oil prices as adequate downside protection; highly risk averse companies may choose to lower this risk-adjusted hurdle price to the $10 per barrel level. However, it should be clearly recognized in project assessment exercises that these worst-case scenario prices are likely not sustainable over time.

Similarly, planners should recognize the much smaller likelihood of upside price potential relative to our base case. Numerous scenarios run by CERI analysts which attempted to force a higher price track for the market were largely unsuccessful. In each case, either negative demand response or positive non-OPEC supply response (or both) served to return the market to a lower price path. **The sequence of events which would be required to achieve a $25 (U.S.) per barrel oil price in 1990 (or even 1995) is largely inconsistent with market fundamentals.** It is true that this conclusion stops short of catastrophic events, such as an escalation in Mid-east tensions or an increase in active foreign military engagement in the Persian Gulf. However, it would be prudent for corporate planners not to base their decisions on such scenarios. In the context of a rational market evolution, there is little likelihood of significant upside price potential relative to our base case. Even if such events did develop, the resulting prices would not be sustainable for any extended period of time.

Our final message for producers concerns the development of megaprojects directed to the production of nonconventional reserves. While new technology and cost reductions will continue to improve the full-cycle economics of such projects, it appears that most of these projects carry supply prices near or above our reference price path for the mid-1990s. Government assistance, justified on the basis of regional development or employment objectives, may be forthcoming to improve the project economics. However, it is debatable whether or not this constitutes an appropriate expenditure of public funds. It may be more economic over the long-term to pursue enhanced production from existing producing regions and to focus attention on alternative sources of crude oil liquids or on alternative sources of transportation fuels, given that the latter is the only sector in Canada which is truly captive to world oil market developments.

Canadian Energy Policy Makers

Energy policy in Canada over the last decade, and particularly policy pertaining to the crude oil sector, has been as volatile as the world oil market. From the highly interventionist federal policies of the late 1970s and early 1980s, with their myriad of pricing, taxation, incentive and support schemes, energy policy in Canada has come almost full circle with the deregulation and decontrol initiatives underlying the Western Accord, Atlantic Accord, and Canada Lands Act. Crude oil pricing, production, marketing and sourcing are all essentially deregulated, a scenario which is viewed favourably by Canada's energy producers as well as by large sectors of the general public.

The move to deregulation of Canada's oil industry has not meant the elimination of provincial and federal government involvement in the oil market. Various provincial royalty concessions and incentive programs are in place in Western Canada to assist in the continued development of Canada's conventional crude oil resource base, and to promote the expansion of nonconventional crude oil production. The federal government announced in July 1988 its intention to significantly underwrite the development of the Hibernia offshore oil reserves, through grants and loan guarantees to the project consortia. Similar actions may be forthcoming in relation to the development of the northern frontier resources, and the expansion of Canada's mined oil sands capacity.

These latter projects represent the upper fringe of world oil productive capacity development, costing billions of dollars to complete and yielding crude oil which will carry among the highest supply prices in the world. Many analysts are questioning the wisdom of such developments (and the fiscal responsibility of the federal government in lending its financial support) in the current climate of excess world oil supply and unstable, weak oil prices. The federal and provincial governments backing these projects are, in turn, pointing to the economic development spin-offs of these megaprojects and the likelihood of rising crude oil prices in the future, as support for their investment of public funds.

The first message to Canadian energy policy makers arising from this study is that, while adherence to long-term market fundamentals and appropriate downplaying of short-term market imbalances are necessary for long-term policy planning, care must be taken to give sufficient weight to the risk associated with long-term price projections. For example, the implicit supply price for the Hibernia project (as understood from publicly available documents) is not out of line with our reference case price projection for 1995-1996, the estimated date of project completion. However, the risk associated with this projection lies almost entirely on the downside; it is feasible that crude oil prices could remain below the implicit Hibernia supply price (estimated by the authors) of $22-$24 ($1988 U.S.) per barrel through the end of the century.

This is not to suggest that public sector involvement in megaprojects is ill-advised. The economic development benefit of such large-scale projects may itself justify the public expenditure component of the development, regardless of the state of the project economics at the time of initial production. However, the magnitude of the public investment and the high degree of uncertainty surrounding the project economics certainly warrant the utmost caution.

The second message to Canadian energy policy makers concerns the upward track of real crude oil prices over the forecast period. While this is good news for the oil producing sector in Canada, it is tremendous news for the energy conservation and alternative energy interests in our country. **Major energy-saving gains remain to be made on the demand side of the oil equation, and alternative energies are positioned to take a greater share of the oil market in Canada.** The trigger to initiate (or re-establish) these activities is a higher crude oil price. Continued research, development and demonstration of these new technologies will lower their supply prices even further, and advance the timing of successful commercialization and application. **It is important that the public sector in Canada pay appropriate attention to these demands and supply measures, and not be overly swayed by the economic development benefits of large project developments.**

Finally, the current study provides implicit support for the current government stance on oil market decontrol and deregulation in Canada. The Canadian oil industry, unfettered by government intervention in the market-place, has proven its ability to withstand severe downward price pressures and to function in a highly volatile market situation. If the industry is similarly allowed to reap the rewards of gradually rising prices in the future, it is equally likely that it will thrive and continue to supply crude oil to Canadians well into the next century. **The future health of Canada's oil industry will once again test the strength of Canada's public sector support for market deregulation; Canadian energy producers and consumers should both hope that this support will remain strong.**

Areas of Further Research

As with any study of this magnitude, this report must be considered a first cut at the complex interrelationships underlying the world oil market. The Institute intends to further its research in this area by updating and refining the analytical framework underlying this study. In the fall of each year, CERI will release an update report to sponsors, discussing the refinements made to the framework and analyzing various policy and market strategies which could impact on the evolution of the world oil market. The Institute encourages CERI sponsors and interested readers to forward their ideas for future analysis to the Institute to assist in making these updates as relevant and comprehensive as possible.

Following is a brief discussion of the refinements which CERI intends to make to the analytical framework over the next few years.

Third World Markets

The current analysis provides a fairly accurate representation of supply and demand characteristics of the oil markets of the developing countries. Established and ultimate potential reserves estimates, operating and capital costs, product demand profiles, and other aspects of these markets have been extracted from numerous sources and, where possible, validated by reference to producers operating in the various regions.

The growth of crude oil demand in the developing countries, and their ability to source these requirements from indigenous supplies, are critical elements in the evolution of the world oil market. If expected economic development in these countries is to be fuelled by crude oil purchased on the world market, one can anticipate a tightening of the market and an accompanying strengthening of crude oil prices. Alternatively, the ability of the developing countries to source their crude oil requirements internally will, to a large extent, determine the duration of the excess supply situation currently overshadowing the world oil market.

The Institute will be examining in greater detail the pattern of future reserves additions, productive capacity, and crude oil demand growth in the developing countries, beginning with an assessment of potential developments in Central and South America. Research will be undertaken in collaboration with industry and government officials experienced in the analysis of these particular oil markets.

Interfuel Substitution

The development of a more detailed representation of interfuel substitution (or "switchable" product demand) will be undertaken within the context of a more thorough investigation of the relationship between crude oil prices and end-use product prices. More specifically, future versions of the analytical framework will contain explicit feedback loops between crude oil prices and economic growth, and a preliminary representation of fiscal variables affecting the relationship between crude oil and product prices.

The primary focus of this analysis will be on the OECD countries, where technological penetration has enhanced the ability of industrial and commercial energy consumers, in particular, to react quickly to relative price changes among competing fuels. The switchable fuel market represents an increasingly important buffer against increases in real crude oil prices, particularly in North America and Europe where rapidly maturing natural gas distribution networks provide a ready competitor for escalating petroleum product prices. Initial research in this area will focus on Canada and the United States.

Centrally Planned Economies (CPEs)

The ability of the CPEs to maintain or increase net crude oil exports to the western world will have an important bearing on future crude oil prices. The need for foreign currency earnings to finance the economic restructuring of the Soviet bloc countries provides a tremendous incentive for maximizing crude oil exports. The success of the Soviet program to increase natural gas penetration (and off-oil conversions) within the Soviet economy, and the ability of the Soviet petroleum industry to prove and develop significant crude oil reserves in the increasingly harsh and remote areas pinpointed for future exploration activity, will ultimately determine the availability of CPE crude oil export volumes in the coming years.

The Institute will access industry experts on the Soviet economy in order to clarify the key policy, technical and geological considerations underlying future crude oil and natural gas developments in the CPEs. This information will then be incorporated within realistic scenarios of CPE net exports and their impact on the world crude oil market.

Reserves Additions and Production Costs

The marginal cost of operations in producing fields and the full-cycle cost of developing new reserves represent, in large part, the lower and upper bounds for crude oil price movements over the medium term. The current framework contains a sophisticated methodology for analyzing reserves additions, development and production within the non-OPEC producing countries.

An ongoing facet of Institute research will be to further refine the representation of drilling activity, finding rates, productive capacity and supply costs within the analytical framework. Industry and government sources around the world will be contacted to provide additional insights and to validate the data underlying the supply side of the modelling framework. It is critical to the analysis of future market strategies and price scenarios that the framework accurately represent half- and full-cycle production economics, in order to provide an accurate representation of non-OPEC supply response to potential future developments in the world oil market.

Uncertainty Analysis

Regardless of the accuracy with which one represents the current structure of the world oil market, it is impossible to fully predict the market response to potential supply and demand developments. Inaccuracy of established and ultimate potential reserves estimates, effects of technological improvements on finding and development costs, improved seismic and geological data analysis, lags in conservation and energy efficiency initiatives, irreversibility of energy efficient technologies, consumer expectations regarding future price developments, and a host of other tangible and intangible factors introduce a significant degree of uncertainty into the analysis of future developments in the world oil market. Analysis of alternative scenarios predicated on changes to key variables can provide a feel for the degree and impact of market uncertainty, but does not capture the linkages among the variables underlying future market development.

In designing the framework for analysis of the world oil market, CERI researchers accounted for uncertainty analysis by developing a framework conducive to the adoption of probability (or Monte Carlo-type) analysis of key variables underlying future market development. In the next round of research in this area, the existing model will be linked into an uncertainty analysis environment. By representing the analyst's perception of market uncertainty through the development of probability distributions around the most-likely value of key market variables, crude oil price projections will better reflect the degree of upside and downside risk accompanying these projections. In this way, users of the CERI world oil market reports will be better able to incorporate market uncertainty within their own planning and corporate strategies.

This report is the beginning of a body of research which the Institute believes will assist the Canadian energy sector in better understanding the forces underlying the evolution of the world oil market. The refinements anticipated for the analytical framework, combined with the increasing quality of oil market expertise housed within the Canadian Energy Research Institute, will make these annual reports on the world oil market an important and valuable contribution to the understanding of energy issues in Canada.

Chapter 1

INTRODUCTION

1.1 Objectives and Study Structure

The dramatic oil price crash of 1986 evidenced the ability of the OPEC cartel to disrupt and destabilize the world oil market through price erosion as well as price increases. In the aftermath of this third oil price "shock" in less than 15 years, the Board of Directors of the Canadian Energy Research Institute instructed CERI staff to undertake a detailed analysis of the fundamentals of, and outlook for, the world oil market. The objective of the exercise was to develop a methodology for analyzing alternative assumptions and scenarios regarding the future path of the oil market and crude oil prices, to aid Institute sponsors in medium- and long-term corporate planning and energy policy development. The framework for analysis was to be sufficiently detailed, comprehensive and disaggregate to allow examination of, among others, the following question: In the event of a complete collapse of the OPEC cartel and the development of a "competitive" world oil market structure, what would be the most-likely path for crude oil prices, in what countries or regions of the producing world would output be affected, and to what extent?

The ability to properly analyze such potential market developments requires the capture of demand response to price and income changes, the cataloguing of established and potential reserves in producing regions around the world, an accurate representation of capital and operating costs, drilling activity and success rates in the various regions, and numerous other technical and economic relationships underlying the discovery, production and consumption of crude oil. To accurately represent these relationships requires, in turn, the development of an analytical framework able to accommodate large volumes of detailed information at the individual country level.

In studies such as this, the quality of information underlying the analysis is critical to the accuracy and reasonableness of the final results. To aid in this exercise, the Institute brought together an Advisory Committee of Canadian experts in oil market operations and analysis, drawn from both the private and public sectors, and a Technical Advisory Committee, composed of recognized experts in world oil market modelling and analysis, to comment on the methodology, data, and final draft of the study. To further ensure that our representation of world oil market supply and demand was as accurate as possible, the inputs used to represent key market factors (e.g., established reserves, ultimate potential reserves) were vetted not only through the Committee members but also through companies operating in the various regions of the world represented in this study.

The end result of these efforts is an analytical tool of tremendous value, flexible enough to accommodate the analysis of a wide range of policy options and alternative scenarios, and sufficiently detailed to generate important insights regarding the linkages and interrelationships underlying the operations and evolution of the world oil market. Combining this powerful analytical tool with the energy market expertise housed within the Canadian Energy Research Institute has resulted in this, the first in a series of reports to be produced by CERI on the operations of, and outlook for, the world crude oil market.

The study is organized as follows. The remainder of this chapter provides a brief discussion of world oil market developments since the early 1970s, identifying the fundamental characteristics and features of the market which must be captured in addressing the evolution of the market through to the end of this century. Chapter 2 examines the history and current structure of world oil demand, analyzed in terms of demand for crude oil products in the various regions. A number of key factors and fundamental trends in crude oil consumption are identified, which can be expected to play an important role in future oil demand. Chapter 3 provides an examination of the history and current structure of world crude oil supply, emphasizing the methodology employed in representing crude oil production, reserves additions and productive capacity development within the CERI analytical framework. In both chapters, a series of sensitivity cases are presented, in order to provide the reader with an intuitive understanding of the effect of changes in key variables on regional and total crude oil demand and supply.

Chapter 4 provides the reference case crude oil market scenario generated by the integration of the demand- and supply-side analyses. The reference case is discussed in sufficient detail to allow the reader to apply the results to his or her own particular circumstances or concerns. A series of alternative market scenarios are also presented, to provide additional insights into the implications for market evolution of various assumptions regarding the potential development of world oil market structure and conditions.

Finally, in Chapter 5 the study authors draw together the critical conclusions arising from this analysis and provide a discussion of the implications, and key messages, for Canada's crude oil producers and consumers.

The chapter concludes with a discussion of the future research program the Institute intends to undertake, to modify and enhance our ongoing analysis of the world's evolving crude oil market.

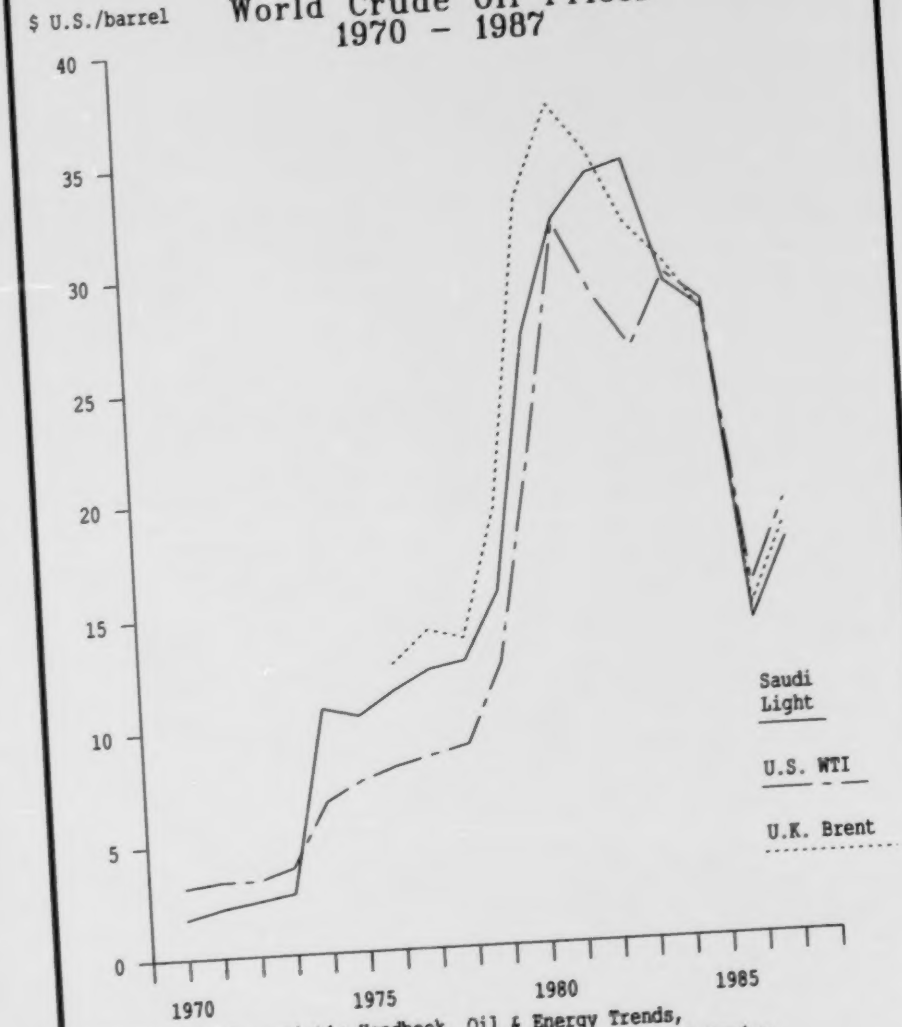
1.2 The World Oil Market: Inherent Instability

Over the last 15 years, the world market for crude oil has proven to be one of the most volatile of all commodity markets. A potent and largely unpredictable combination of international political factors, powerful economic changes, and surprising technological advancement has contributed to this volatility. These forces have exerted a continuing and dramatic influence on the economic performance of both the industrialized market economies and oil-exporting nations. Since 1973, crude oil has followed an evolutionary pattern from one of the most plentiful and cheap of energy commodities to one of the most scarce and dear, only recently reverting back to a comparatively inexpensive energy form traded in conditions of considerable over-supply. The price of crude oil over this period has fluctuated over an incredible range, from as low as $3 (U.S.) per barrel to as high as $35 per barrel (see Figure 1.1).

What explains this historical pattern of volatility, which has been the source of so much upheaval in the global economy? Certainly one of the most important and fundamental factors at play has been the basic geological fact that the world's petroleum resources have been distributed very unevenly. The world's proven reserves of crude oil (outside of the centrally planned economies, or CPEs) were estimated to exceed 800 billion barrels at the end of 1987.[1] Of this total, some 670 billion barrels--or about 84 percent--are located in the 13-member nations of the OPEC. About 560 billion barrels--70 percent of the non-CPE total--are found in the countries of the Persian Gulf region alone. This extreme concentration of the world's crude oil reserves suggests that world oil supply will depend first and foremost on the economic and political strategies adopted by OPEC in general, and by a handful of Persian Gulf nations in particular.

Another key variable has been the changing role of oil in the world economy, and particularly in the industrialized OECD countries. The 1950s and 1960s witnessed rapid market penetration and demand growth for crude oil in these countries. This was due to high and sustained economic growth, the relative ease of production, transportation and utilization of crude oil-derived products, and the substitution of abundant, inexpensive oil for less convenient fuels such as coal. This dramatic increase in demand laid the foundation for the sharp oil price increases of the 1970s. The subsequent and

Figure 1.1
World Crude Oil Prices
1970 - 1987



SOURCE: Oil Economist's Handbook, Oil & Energy Trends, API Basic Petroleum Data Book, B.P. Statistical Review, Petroleum Intelligence Weekly.

equally dramatic economic response to high oil prices, in turn, set the stage for the erosion of oil prices in the 1980s.

The link between oil demand and economic growth in the OECD countries has been weakened in the last decade by changes in the economic structure of the industrialized economies (gradual increase in importance of the service sector), by cost-inspired breakthroughs in the technology of crude oil conservation (e.g., more efficient automobiles, improved home insulation), and by development of interfuel substitution (in particular, the use of natural gas, coal and electricity by industry). While energy efficient technologies and energy conservation have gradually become embedded in the capital stock and operating procedures of the industrialized nations, a critical question for the world oil market is whether or not the continued economic development of the Third World countries will be fuelled by petroleum products or other, indigenous energy sources, and to what extent these countries will be able to adopt the energy efficient (and relatively expensive) production technologies being employed by the industrialized nations.

Technology has also played a key role in the oil market, particularly on the supply-side and more particularly in the high-cost, non-OPEC producing areas. A combination of high oil prices and technological advancements sparked the development of crude oil production in nonconventional areas during the 1970s and 1980s. These included North Sea oil, Canada's oil sands and bitumen deposits, and discoveries in remote regions of Latin America, Africa and Asia. Continuing technological improvements are allowing these projects to survive and even thrive in the current era of weak oil prices, and may soon unlock the productive potential of Canada's northern and east coast offshore reserves, among other nonconventional developments.

1.3 Historical Overview

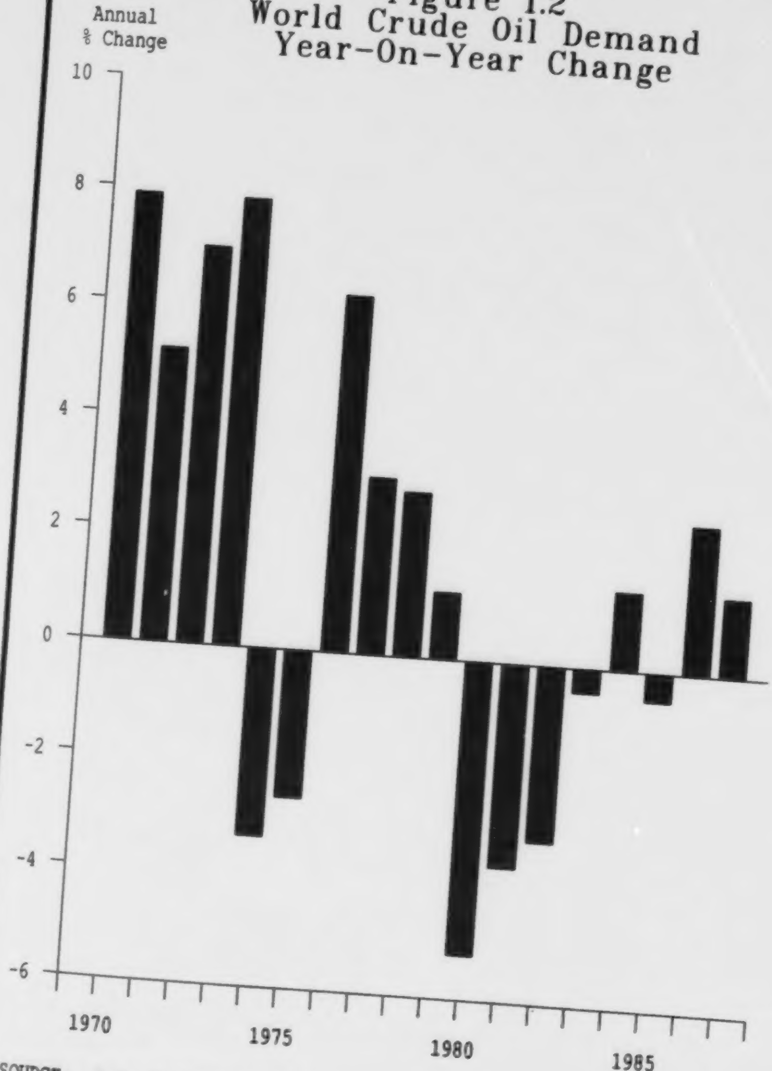
Three key elements--the inherent economic and political instability of OPEC and the Persian Gulf, the changing role of oil in the world economy, and the technology of non-OPEC crude oil supply--help to explain the turbulence of the world oil market over the past 15 years. Prior to 1973, the oil market was characterized by cheap and abundant supply, rapidly growing world demand, and gradual but steady decreases in real crude oil prices. The world petroleum industry was dominated by a handful of international corporations, which controlled the supply of crude oil right from the oil field to the corner gas station, and which coordinated their production and pricing policies on a worldwide basis. It was a time of stability, marked by extensive horizontal and vertical integration.

By 1973, a conjuncture of economic and political factors set the stage for the first of the oil price "shocks." OPEC members were keenly aware of the growing importance of their crude oil resources to the OECD economies, an importance that seemed in glaring contradiction to the low and declining prices OPEC received for its oil exports. The Yom Kippur war--which pitted Israel (backed by the United States) against Egypt and Syria (backed by the Arab world)--provided the political and strategic incentive for OPEC to finally exercise the economic clout which it was now capable of yielding. A blockade on oil shipments to the U.S. pushed oil prices up by 300 percent. These increases were later made permanent by the implementation of high fixed export prices for most OPEC crude oils. Shortages, black-outs and gas station line-ups created a new and widespread fear of impending energy crisis.

This price shock helped to set off a recession in Europe and North America, which temporarily reduced crude oil demand in 1974 and 1975. But with economic recovery came a renewal of demand growth in the OECD countries, which subsequently reached annual growth rates almost as high as the pre-1973 era (see Figure 1.2). By 1979, world demand had soared to record levels, and even the OPEC countries were pumping at full capacity. The stage was set for yet another dramatic price increase, and once again the spark was provided by strategic and political developments in the Middle East: the Iranian revolution and the subsequent Iraqi invasion of Iran, which together knocked out almost 80 percent of crude oil production in the two countries by the end of 1980. Panic trading sent oil prices on free markets rocketing up by another 300 percent, with OPEC's official export prices eventually following suit.

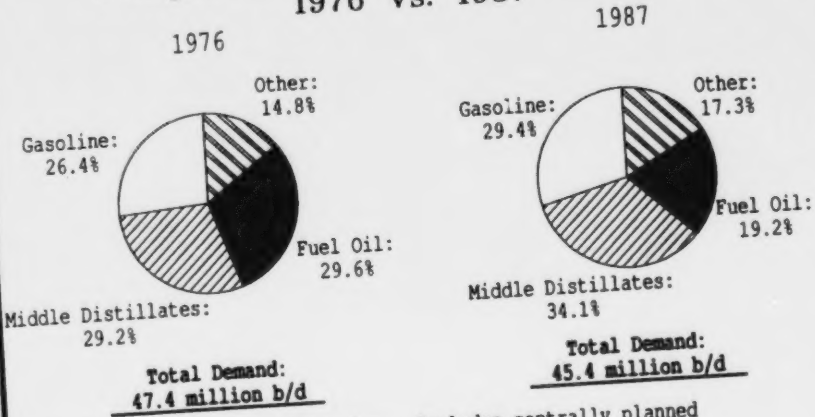
The reaction to this second price shock was fundamentally different from the case of the 1973 price increases. Once again, a world-wide recession cut sharply into oil demand, but this time demand continued to fall even after economic recovery. Conservation and fuel substitution reduced the consumption of refined petroleum products, especially that of heavy fuel oil. Demand came to be concentrated in those uses (transportation, lubricants and chemicals, and some home heating) for which substitutes to oil products were most difficult to develop (see Figure 1.3). Equally important, high oil prices and improved production techniques inspired a steady increase in crude oil supply from non-OPEC regions (see Figure 1.4), where total output expanded by an average of one million barrels per day (MMb/d) per year between 1979 and 1985. Most of this increase came from two huge producing regions alone--the North Sea and Mexico--but exploration and development booms in dozens of other areas (notably Colombia, Malaysia and Egypt) also added significantly to total non-OPEC supply.

Figure 1.2
World Crude Oil Demand
Year-On-Year Change



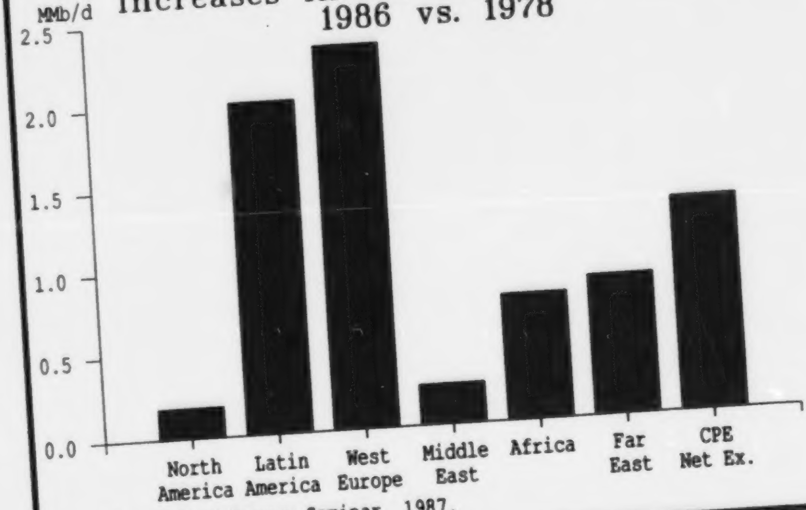
SOURCE: B.P. Statistical Review.
Excludes centrally planned economies.

Figure 1.3
Composition Of World Oil Demand
1976 vs. 1987



SOURCE: B.P. Statistical Review. Excludes centrally planned economies; "Other" includes lubricants, solvents, refinery fuel, and petrochemical feedstock.

Figure 1.4
Increases In Non-OPEC Production
1986 vs. 1978



SOURCE: Oxford Energy Seminar, 1987.

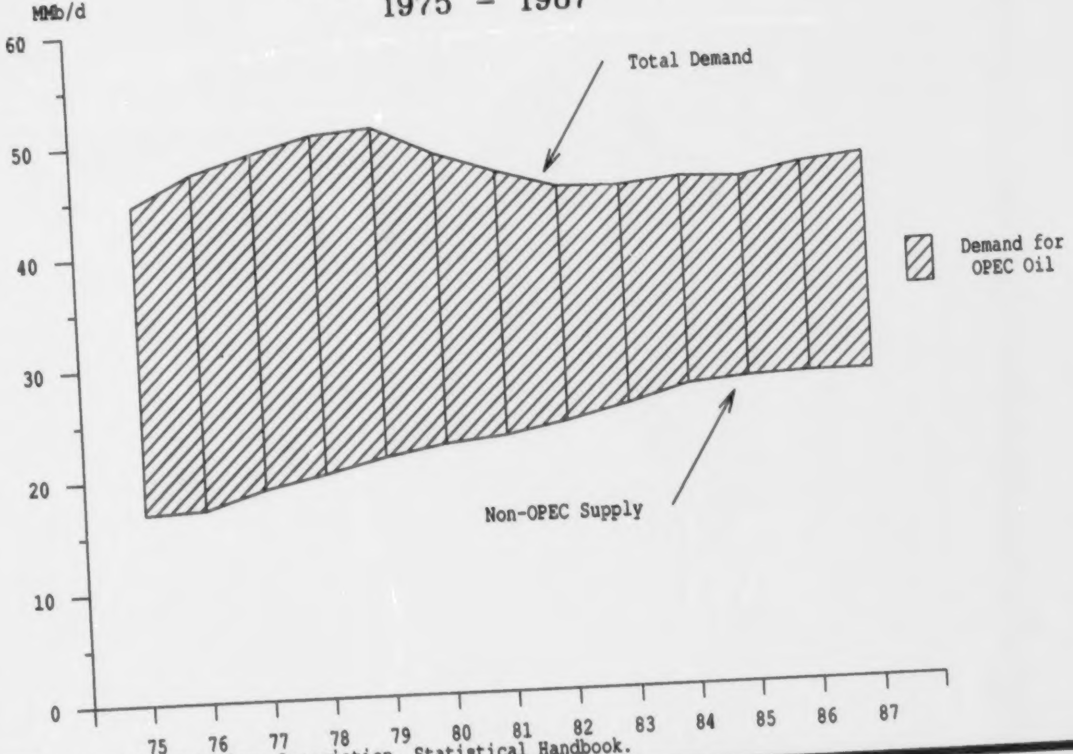
OPEC found itself caught between the pincers of increasing non-OPEC supply and stagnant world oil demand which, given the cartel's historic role as residual supplier to the world market, combined to reduce both OPEC's market share and its absolute volume of production (see Figure 1.5). Between 1979 and 1985, world demand for crude oil (outside of the CPEs) fell by over 5 MMb/d, while non-OPEC supply (including net exports from the CPEs) grew by some 6 MMb/d. The responsibility for defending high prices fell squarely on the shoulders of OPEC, which cut back its own production in an attempt to defend the artificially high market-clearing prices set by the cartel. By the summer of 1985, total OPEC output reached an intolerably low level of 14 MMb/d, or less than one-half of peak productive capacity established in the late 1970s. It became clear that the cartel's strategy had to change.

The change, coming in the form of a concerted effort to expand OPEC's share of the world oil market, was dramatic indeed. Spearheaded by Saudi Arabia's decision to increase production from 2.0 MMb/d to its official OPEC quota level of 4.5 MMb/d on the strength of so-called "netback pricing" arrangements, crude oil prices fell by 50 percent between September 1985 and February 1986, and to less than $10 (U.S.) per barrel by July 1986.

This lesson in marketing was not lost on the cartel members. The revenue implications of high output and low prices proved to be as unacceptable as those associated with high prices and low output. Perhaps most surprising and instructive was the lack of supply contraction by non-OPEC producers in response to the dramatic price decline. The effect of technological advancements and improvements in operating efficiency, substantial manpower reductions in most regions, and the treatment of past capital expenditures as "sunk costs" in assessing operating decisions, allowed non-OPEC producers (with the exception of stripper-well capacity in the U.S.) to avoid costly shut-ins by covering operating costs at the lower price levels. Crude oil production in 1986 was actually higher than in 1985 for Western Europe, Africa, Australasia and Canada, and down only slightly in the United States.[2]

In the fall of 1986, OPEC reverted to its traditional role of swing producer, reinstating production quotas for its member nations and presiding over a modest recovery in prices. Real crude oil prices, however, are still languishing at less than 50 percent of their 1980 levels, and there is every indication that the key OPEC members (particularly Saudi Arabia and Kuwait) wish to keep them there for at least the near term. OPEC's desire to receive the highest possible return for its crude oil exports has been strongly tempered by the equally critical objective of maintaining its long-term market share in the current soft-market environment.

Figure 1.5
Demand For OPEC Oil
1975 - 1987



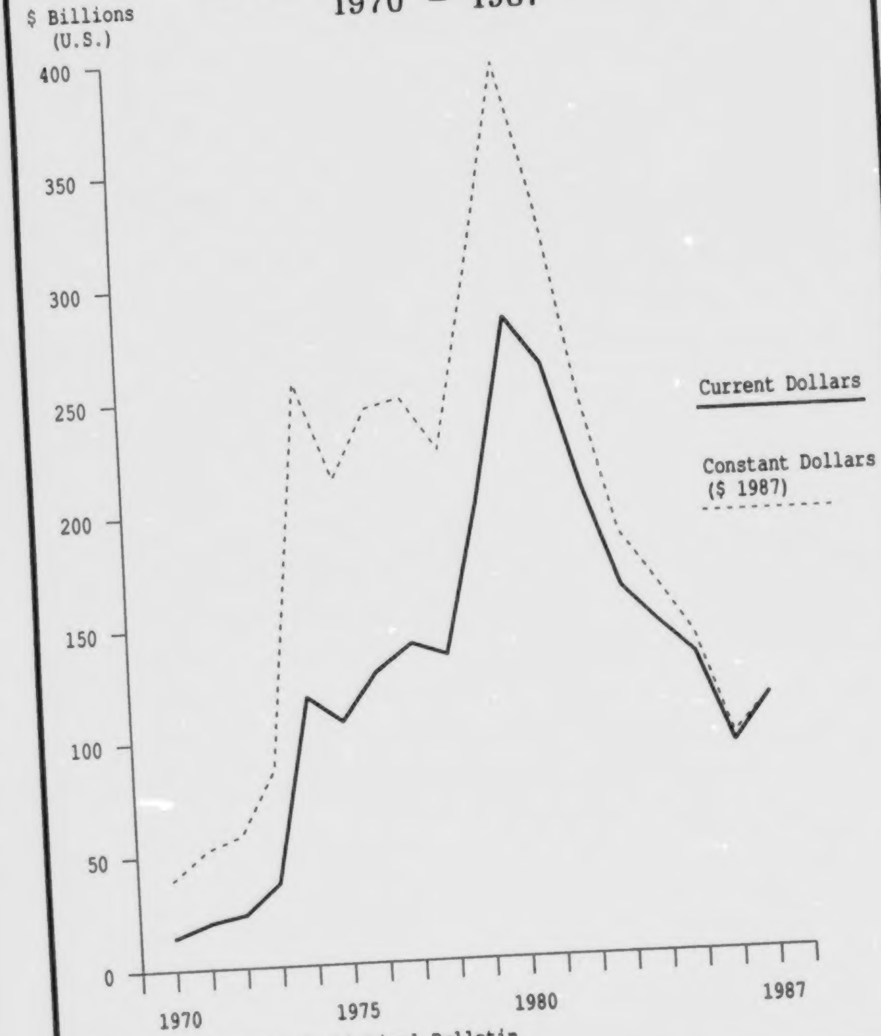
SOURCE: Canadian Petroleum Association, Statistical Handbook.

Amidst these dramatic year-to-year price fluctuations, world oil trade has undergone a number of more fundamental structural changes and qualitative developments that have profoundly altered the manner in which crude oil is produced and sold. One of the more obvious of these changes has been the evolving role of OPEC as the major player on the world oil stage. OPEC started out in the 1960s as a relatively weak and passive producers' association. By 1973, the organization exhibited a much higher degree of militance and determination; many OPEC governments had nationalized their respective petroleum industries, and an emerging political orientation of nationalism, pan-Arabism and solidarity with other developing countries fuelled OPEC's drive for higher prices. Through the late 1970s, OPEC seemed to conform to the all-powerful and closely-knit stereotype of the western mass media, but this image started to fade in the 1980s as OPEC's revenues were squeezed by the twin pressures of increasing non-OPEC supply and eroding world demand.

The OPEC of 1988 is a wiser and still influential conglomeration of the world's most important crude oil producers. However, events have coincided to loosen the cartel's once powerful grip on world oil market developments. Real petroleum revenues last year were only one quarter of what they were in 1980 (see Figure 1.6), and several OPEC members (including Venezuela, Nigeria, Indonesia, Iraq and even Saudi Arabia) are facing severe fiscal and foreign debt pressures. The strains of collectively restricting production to some 60 percent of capacity have been showing more clearly; Iraq has formally withdrawn from OPEC's system of production quotas, while other members (such as the United Arab Emirates) routinely flaunt their quotas. Above all, the stalemated Iran-Iraq war has handcuffed the organization, forcing vulnerable Persian Gulf producers such as Iraq, Kuwait, and Saudi Arabia to put national security concerns ahead of efficient oil market strategies. At the time of writing this report, it remained unclear exactly what effect the ceasefire in the Iran-Iraq war would have on OPEC production and, hence, on world oil prices.

The size and persistence of these non-OPEC sources of supply represents a second important structural development in the world oil market over the past decade. Despite OPEC's dominant share of proven crude oil reserves, its share of productive capacity is limited for the time being by the significant development of more expensive supply sources outside of OPEC. Non-OPEC supply has continued to grow in the period since the 1986 crude oil price crash, by a net total of 500,000 b/d, or about 2 percent. New projects in a host of different countries are more than offsetting declining capacity in the United States, and most observers expect that non-OPEC supply will be able to more than hold its own over the next 5

Figure 1.6
Estimated OPEC Revenues
1970 - 1987



SOURCE: OPEC Annual Statistical Bulletin.

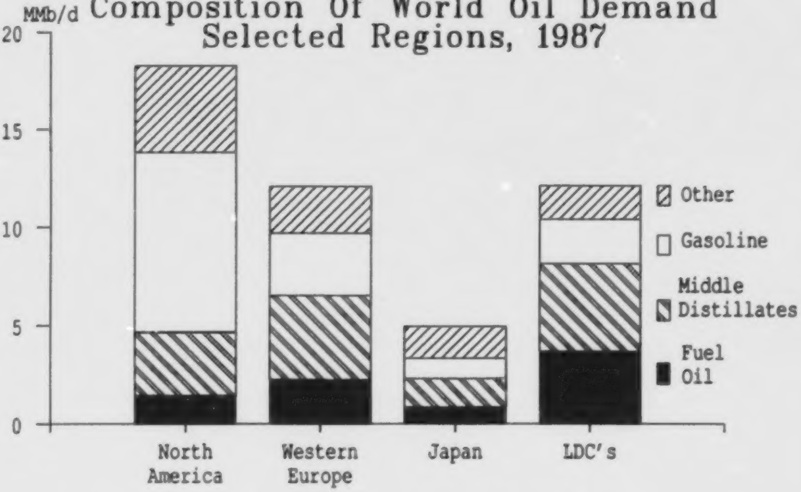
years, assuming that world prices stay at least in the $15-$18 (U.S.) per barrel range. Continuing improvements in the technology of crude oil supply (including areas such as deep-sea well completions and computer-assisted seismic data interpretation), together with decreased taxes and royalties in many producing countries, should ensure that non-OPEC supply will constrain OPEC's attempts to increase its market share for some time.

The changing composition of crude oil demand is a third feature of modern oil trade. There is a tendency towards increased consumption of gasoline, middle distillates and speciality products at the expense of heavy fuel oil--in other words, a "lightening" of the crude oil demand barrel. In addition, demand in the less developed countries (LDCs) is accounting for a growing share of world consumption (see Figure 1.7). Industry in these countries is still reliant on oil products, relative to the OECD countries. It is difficult to say what effect these structural changes will have on future crude oil demand and price trends. Foreign debt and economic crisis could constrain future demand growth in much of the Third World, and the fact that fuel oil makes up such a large share of total LDC demand suggests that there exists considerable potential for oil conservation and substitution in coming years. In the OECD countries, demand is now centered on the lighter refined products for which future conservation gains will be harder to achieve, although technological and structural developments (such as the electronics revolution, the growth of the service economy, and the potential of superconductivity technology) could all profoundly affect crude oil demand in the decades to come.

1.4 Summary

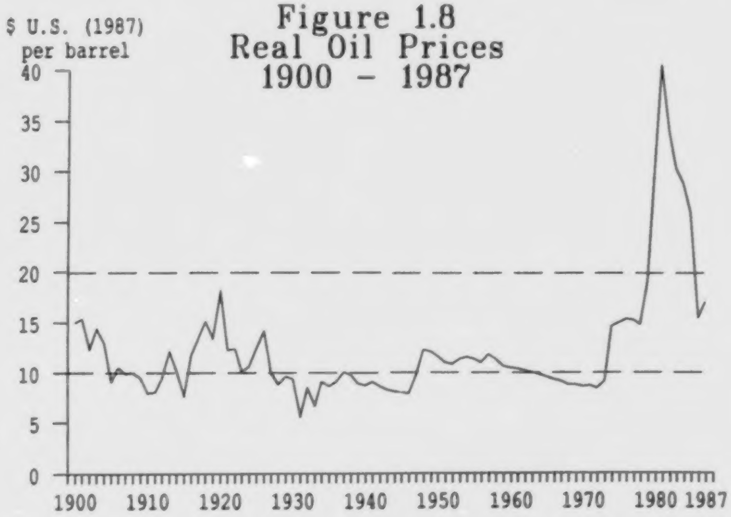
After 15 years of wide price fluctuations and market instability, the world oil market in 1988 has ended up almost where it began in 1972. Indeed, for most of this century, real oil prices have fluctuated between $10 and $15 per barrel (in 1987 $U.S.), only marginally below current levels (see Figure 1.8). Some observers project that continuing cost reductions and new resource developments on the supply side of the oil market, enhanced inter-fuel substitution and multi-fuel capability on the demand side of the market, and a gradual erosion of OPEC's monopoly power, will keep oil prices at or near current levels for some time. Other observers cite these same factors as contributing to increased market instability and increased potential for a severe market crash. Still others suggest that OPEC will successfully manage the oil market, gradually rebuilding its market share over the next decade. Certainly the long-term fundamentals are on the side of the OPEC cartel, and particularly the reserves-rich nations of the Persian Gulf.

Figure 1.7
Composition Of World Oil Demand
Selected Regions, 1987



SOURCE: IEA Oil Market Report, B.P. Statistical Review.

Figure 1.8
Real Oil Prices
1900 - 1987



SOURCE: Salomon Brothers. Uses U.S. average wellhead price.

The objective of the following chapters is to isolate the supply- and demand-side market fundamentals which will necessarily underlie the evolution of the world oil market to the end of the century. It is fairly safe to say that our price projections will not prove to be accurate; no analytical framework can account for the timing and magnitude of changes in the key factors determining market price, nor can an analyst accurately predict the timing and magnitude of political and social upheavals, or changes to energy policy. However, as we have seen in the past, it is the fundamental characteristics operating on the supply and demand side of any market which will ultimately determine the direction and development of that market. Energy planning and energy policy must be formulated in recognition of these medium- and long-term considerations, as well as in recognition of near-term constraints and opportunities. This study provides a clearer understanding of the medium- and long-term evolution of the world oil market and, by so doing, will aid in the development of rational and realistic domestic energy planning, policy and development.

Footnotes

[1] British Petroleum Company, BP Statistical Review of World Energy (London, England: British Petroleum Company, June 1988), p. 2.

[2] Ibid., p. 15.

Chapter 2

WORLD OIL DEMAND

2.1 Introduction

There is an emerging consensus amongst many oil market analysts that it is the future course of world oil demand that will make or break OPEC's crude oil pricing strategy over the next 15 years. To be sure, the other key elements of the world oil market equation will continue to exert a crucial and unpredictable impact on oil prices: future trends in non-OPEC supply, the technology of alternative energy systems, and the internal dynamics of OPEC itself. But there is an increasing preoccupation with the uncertain prospects of world demand growth, which may turn out to be the most decisive of the numerous oil market unknowns.

World oil demand trends have played a central and dramatic role in shaping previous oil market developments. It was the huge annual increases in world demand of the 1960s and early 1970s that laid the groundwork for OPEC's ascendancy during the Yom Kippur War of 1973. With a world economy increasingly reliant on Persian Gulf oil to meet its burgeoning energy needs, OPEC was well-placed to start dictating terms, both economically and politically. Later, it was the forces of world demand that served to humble OPEC. During the 1980s, gains in energy efficiency and conservation--together with increases in non-OPEC oil supply--cut deeply into OPEC's market share, eventually precipitating the netback marketing campaign and subsequent crude oil price crash of 1986.

Now, in light of OPEC's tortuous, semi-successful efforts to recover from that debacle, analysts are agreed that OPEC's market power can only be restored through strong and steady increases in world crude oil consumption. Non-OPEC oil supply has managed to hold its own in the period since the 1986 price crash, and is expected to continue to do so until close to the end of this century. It is growth in demand, therefore, that must open up more room in the world oil market for OPEC exports, in order to ease the internal strain on the cartel's production quotas and set the stage for price increases later in the 1990s.

Clouding the outlook for world demand growth over the next 15 years is one primary uncertainty: how responsive will demand be in the longer run to the dramatic price decrease of 1986? The initial, immediate effect of lower prices has been significant but not overwhelming. In 1986, non-CPE demand grew by 2.6 percent, the largest year-on-year increase in world demand since before the Iranian revolution in 1979 (see Figure 2.1). In subsequent years, the demand trend has been more modest, but still represents a sharp departure from the stagnant demand of the early 1980s.

If world oil demand picks up over the next 3 to 5 years, then it is reasonable to expect that OPEC will be "back in the driver's seat" by the middle of the next decade, able to preside over large real price increases toward the end of the century. On the other hand, if the demand growth of the past 2 years has been only a one-time response to the sharp fall in oil prices, so that the longer-term demand trend reverts to one of relative stagnation, then oil markets will continue to be plagued by problems of excess capacity, production restraint, and chronic world over-supply. This scenario carries little likelihood of real price growth over the coming 15 years. In this way, OPEC's longer-term prospects are inextricably tied to the outlook for world demand.

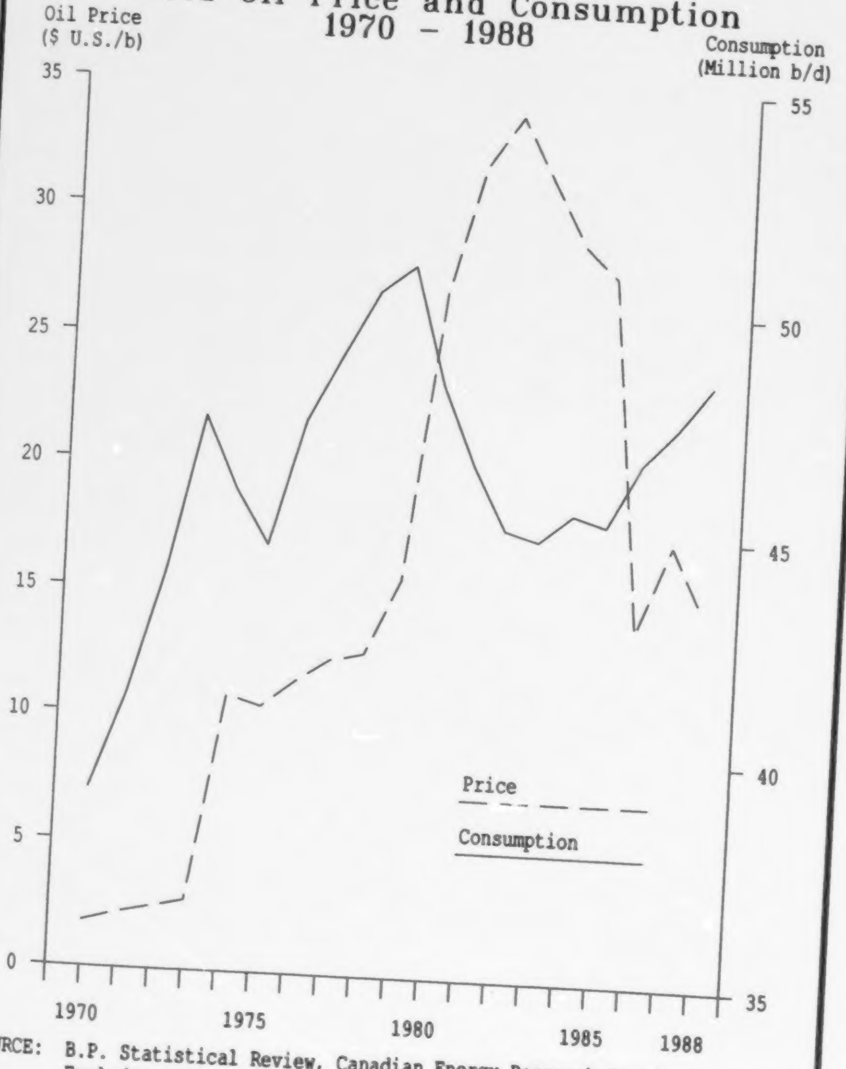
A great many questions surround the issue of the demand response to lower oil prices. Has the theme of energy conservation been permanently "built-in" to both the technology of energy-consuming equipment and the mentality of energy consumers, or is conservation reversible? To what extent will the link between economic growth and crude oil demand--a link that was weakened by the price increases of the 1970s--be restored by weak oil prices? What share of the savings resulting from lower crude oil prices are being diverted to governments (through higher taxes) and refiners and distributors (through higher margins), rather than being passed on to consumers in the form of lower petroleum product prices? In what products and in which regions of the world is future demand growth likely to be concentrated?

The demand side of CERI's World Oil Market model addresses these and other issues in its effort to interpret and forecast world crude oil consumption. The next section of this chapter assesses world oil demand, providing a brief historical and statistical overview of the important qualitative and quantitative characteristics of crude oil demand. Section 2.3 will address some of the conceptual and empirical problems encountered in modelling world oil demand. The chapter concludes with a condensed description of the demand-side formulations that have been adopted in this study.

2.2 The History of World Oil Demand

The preceding section posed the question: how responsive will world crude oil demand be to the recent decreases in the price of oil? The

Figure 2.1
World Oil Price and Consumption
1970 - 1988



SOURCE: B.P. Statistical Review, Canadian Energy Research Institute, Excludes CPE's. Oil Price Refers to Saudi Light at Ras Tanura. 1988 forecast.

answer to this question, it was suggested, will go much of the way toward determining the call on OPEC's vast crude oil productive capacity in the coming years, and consequently the size of price increases that can be expected.

Historical experience provides some insight into the relationship between crude oil prices and world oil demand. The usefulness of this experience to our understanding of the present situation is somewhat limited, however, by the fact that previous sharp movements in price tended to be in an upward direction. It is impossible to say, therefore, whether a sharp oil price decrease, following years of conservation and efficiency gains, will have a mirror-image effect on demand compared to the sharp oil price increases of the 1970s.

2.2.1 The Impact of Price on Crude Oil Demand

The historical evidence proves that oil demand is responsive to price--dramatically, in some cases, but also slowly, unpredictably, and awkwardly. To examine the relationship between price and demand, the recent history of world oil demand can be divided into four phases: the period prior to 1973; the period following the crude oil price shock of 1973-1974; the period following the second price shock of 1979-1980; and the period following the price decrease of 1986.

In the 1960s and early 1970s, real crude oil prices were remarkably stable, exhibiting a very slight declining trend over the period. With low and stable prices and ample crude oil supplies, world crude oil demand grew very quickly--as fast as 7 to 10 percent per annum in the late 1960s (see Figure 2.2). The industrialized economies were enjoying the final years of the great post-war economic boom, and it was this strong economic growth and rapid increase in living standards that provided the major stimulus for increasing oil demand. There was virtually a 1:1 link between GDP growth and crude oil demand during these expansionary years.

The quadrupling of world oil prices that followed the Yom Kippur War of October 1973 interrupted but did not fundamentally change this pattern of rapid increases in petroleum demand. World oil demand declined in 1974 by over 3 percent, partly due to the Arab oil blockade, and partly because of price-induced conservation measures. Following another modest decline in 1975 (the result primarily of that year's severe economic recession in OECD countries), world demand once again renewed its pattern of fairly rapid expansion.

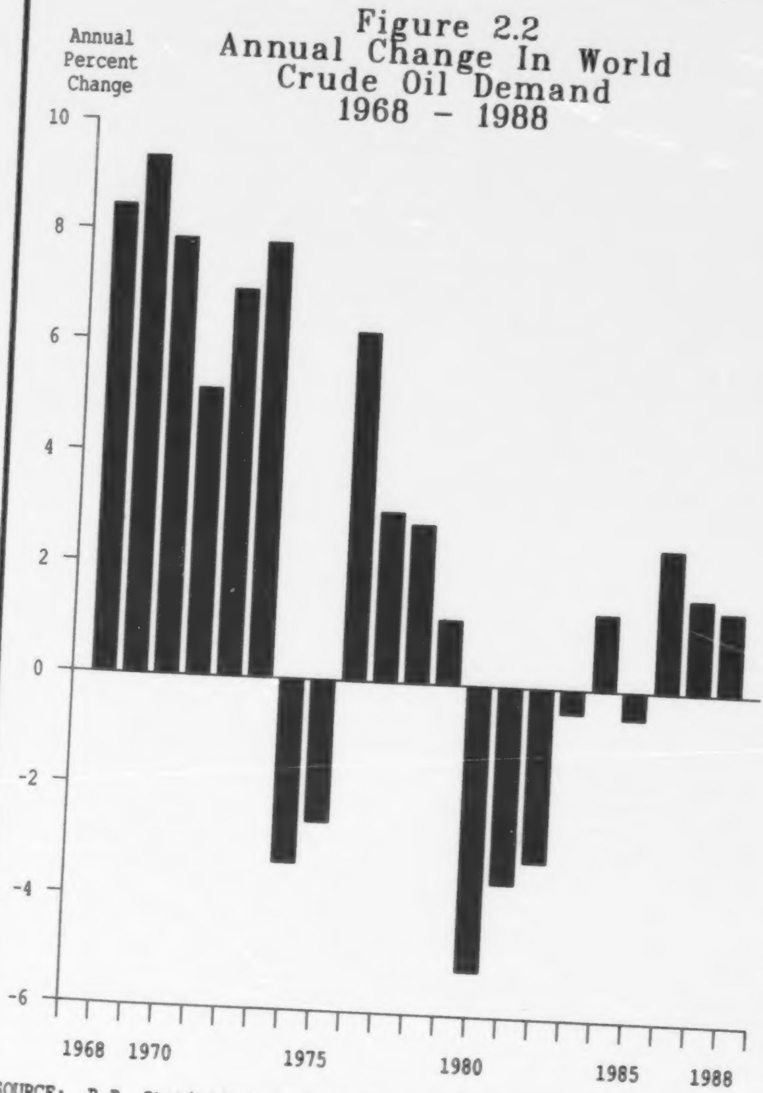


Figure 2.2
Annual Change In World Crude Oil Demand
1968 - 1988

SOURCE: B.P. Statistical Review, IEA. Excludes CPE's.
1988 forecast.

It was not until the second price shock of 1979-1980 that world oil demand was altered fundamentally. The Iranian revolution and subsequent outbreak of war between Iran and Iraq pushed real prices up by over 100 percent, sparking an immediate contraction of world demand by 5 percent in 1980. This time, the immediate decline in demand was followed by further declines in four of the following 5 years--despite the fact that real world oil prices fell by some 25 to 30 percent over the period between 1981 and 1985.

Why did this second price shock have a much more lasting impact on demand than did the first price shock? Some analysts suggest that the 1979-80 price increases pushed the price of oil through a ceiling above which oil lost its competitive advantage as an energy source in many key markets. In other words, while the price increases of 1974-1975 were large in percentage terms, they left the absolute level of oil prices below the point at which widespread fuel substitution and conservation became feasible. After a short-term reaction to the oil embargo and increased prices, world demand could renew its increasing trend, until the events of 1979-1980 pushed oil prices above that ceiling.

Other observers suggest that the second price shock had a more profound impact on the expectations of energy consumers and their governments. Another huge increase in the price of oil, once again motivated by political upheaval in the volatile Middle East, reinforced a crisis mentality amongst consumers, governments and the mass media in the key consuming markets. A consensus emerged that Middle East oil simply could not be relied upon, and major initiatives in the realms of public policy and private energy usage subsequently contributed to a longer-term decline in world oil demand.

Another explanation for the more lasting effect of the second set of oil price increases focuses on the problem of time lags in adjustments to changing energy prices. When the price of oil suddenly changes, there are certain adjustments that consumers of refined petroleum products can immediately make to their consumption habits. Home-owners can adjust their thermostats, automobile owners can adjust the number of miles they drive, and certain industrial energy users can adjust their fuel mix. These short-term adjustments add up to a significant and immediate impact on aggregate oil demand, as illustrated in Figure 2.3. The sharp oil price shocks of 1974, 1979 and 1986 were closely followed by sharp, opposite movements in oil demand in the same or subsequent year.

A much greater cumulative impact on oil demand, however, will be felt if adjustments are made to the energy consuming equipment used by consumers. For example, if home-owners expect an oil price increase to be

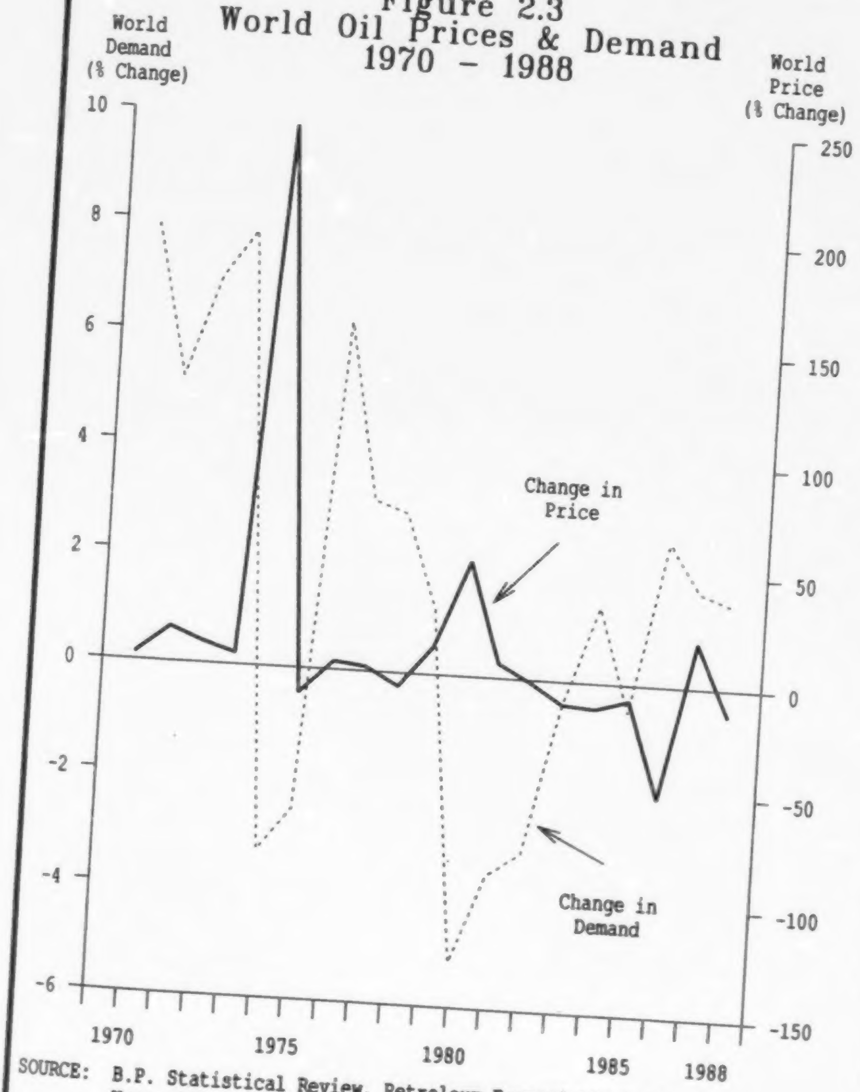


Figure 2.3
World Oil Prices & Demand
1970 - 1988

SOURCE: B.P. Statistical Review, Petroleum Economist's Handbook.
Uses official price of Saudi Light at Ras Tanura. 1988 forecast.

permanent, in addition to simply turning down their thermostat they will invest in a more fuel-efficient furnace, purchase additional home insulation, or perhaps even change their entire heating system to one that depends on natural gas or electricity. Similarly, fuel-efficient automobiles will become more popular, and industrialists will invest in more efficient or dual-fuel power systems. The impact of these measures on oil consumption will be slower in coming, but will have a larger and less reversible effect than the more immediate conservation measures described above.

Therefore, it is suggested, the full effects of the first price shock had not yet been felt by the time consumers had to start grappling with the second set of dramatic price increases. Automobile manufacturers started in 1975 to design smaller and more efficient cars and trucks, but this effort did not translate into reduced gasoline consumption until the end of the decade, after these vehicles were designed, manufactured, and sold in sufficient numbers to make up a significant share of the total fleet of vehicles on the road. Similar time delays were encountered in the other petroleum product markets.

In all likelihood, all three of these factors help to explain why the decrease in world demand that followed the price shock of 1979-1980 was so great and so apparently permanent. First, the price increases of 1979-1980 simply left oil products uncompetitive in many markets, in relative price terms. Second, the 1979-1980 price shock created a widespread expectation that high and increasing oil prices were a permanent feature of the world economy. Third, the immediate effects of the 1979-1980 price increases were accentuated by the lagged effects of the tripling of oil prices 5 years earlier.

By 1985, world crude oil demand (excluding the centrally planned economies) had fallen by 11 percent, or over 5 MMb/d, from the peak levels of 1979. As OPEC watched its production levels shrink to a 20-year low of barely 14 MMb/d in the summer of 1985, it became obvious that prices were unsustainably high. The events of the next year served to cut world oil prices in half, and OPEC hoped that low prices would both reduce non-OPEC supply and boost world demand. The more moderate, yet persistent, growth in non-OPEC supply has surprised and disappointed OPEC members, but the cartel's strategy has proven somewhat more successful in terms of its impact on world demand. Demand growth between 1986 and 1988 has added about 3 MMb/d to worldwide consumption. Has this been a short-term, one-time adjustment to lower oil prices? Or can we also expect further, longer-term adjustments in capital stock and energy consumption habits to provide a more permanent boost to world oil consumption? To gain further insight into this question, the region-by-region and product-by-product structure of world oil demand must be considered.

2.2.2 The Structure of World Oil Demand

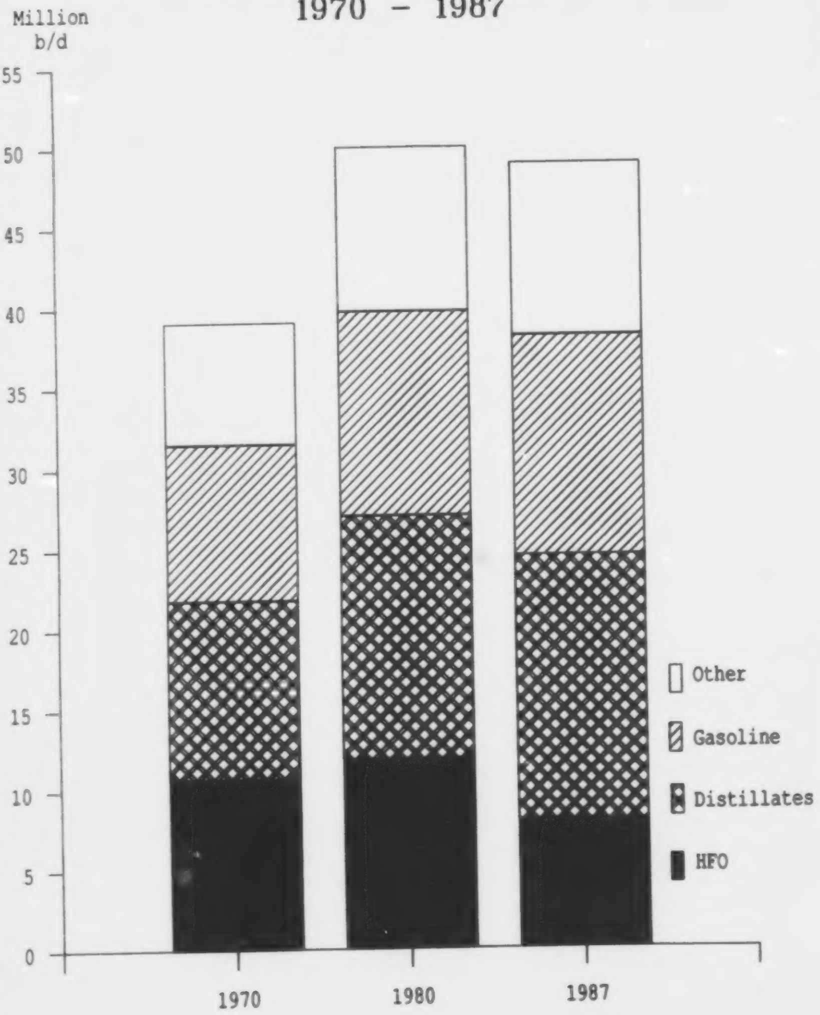
It is not only the absolute level of world crude oil demand that has undergone dramatic changes during the past 15 turbulent years. In addition, the composition of that demand with respect to product and regional consumption has also varied greatly.

In general, there has been a significant "lightening" of the typical crude oil demand barrel since the early 1970s (see Figure 2.4). Lighter refined products, such as gasoline and distillate fuel oils, make up a much greater share of total world oil demand, while the consumption of heavier products such as residual fuel oil has steadily declined. The lighter refined products generally have few, if any, close substitutes to which consumers can turn in the event of price increases. This is especially true of gasoline and other transportation fuels, where demand has been constrained by efficiency gains and conservation, but not to any great extent by a switch to competing fuels. In heavier product markets, however, less expensive substitute fuels (such as coal, natural gas and even electricity) have been called upon for purposes of electrical generation, industrial power and, to a lesser extent, home heating. The demand response to higher oil prices has been much more significant for heavy fuel oil, therefore, than for the other products.

There have been equally significant changes in the distribution of world oil demand amongst the various consuming regions (see Figure 2.5). The most striking development has been the steady growth of oil consumption in the less developed (LDC) economies of the Third World. LDC oil demand has virtually tripled over the past 20 years, to almost 13 MMb/d, or over 25 percent of non-CPE world demand. Oil demand in these countries did not shrink following the price increases of the 1970s, but rather has continued to steadily expand. Average economic growth in the Third World has been somewhat faster than in the OECD regions, partially explaining this faster and more consistent demand growth. A contributing factor here is the inclusion in non-OECD statistics of most of the OPEC countries, where the increase in crude prices over the 1970s actually spurred economic growth and crude oil demand, the latter aided further by domestic price protection. More importantly, economic growth in the LDCs tends to be concentrated in energy-intensive primary production and heavy industry, compared to the service and electronics industries which consume less energy and which have been the main sources of recent economic growth in the more developed countries.

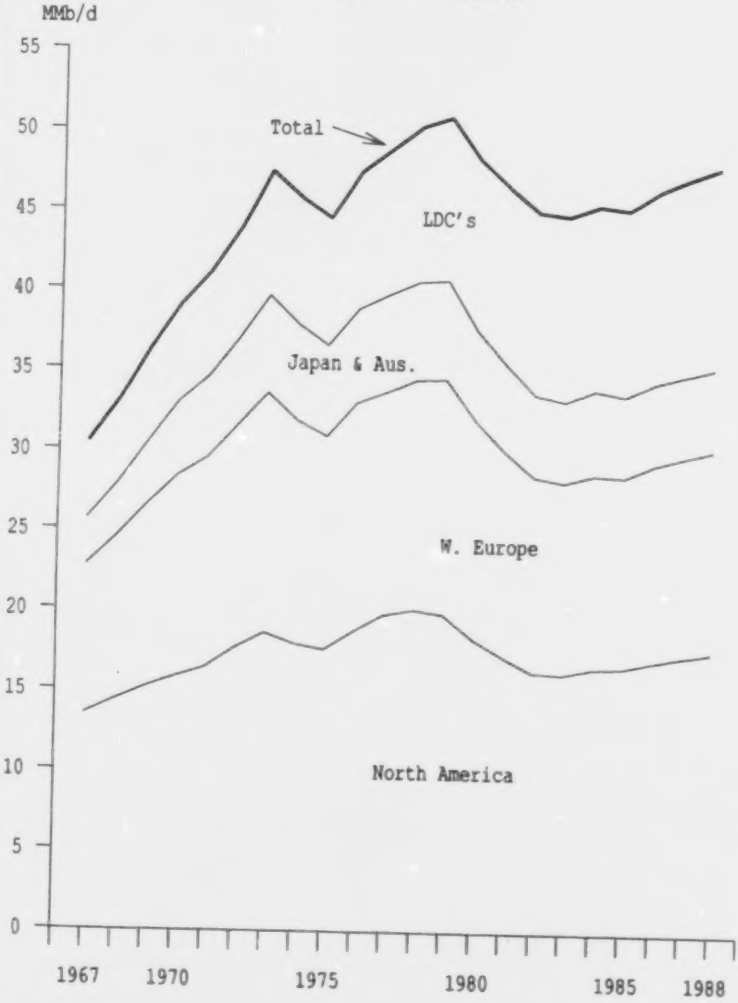
Within the individual consuming regions, there are great differences in the product composition of oil demand (see Figure 2.6). Gasoline makes up the lion's share of petroleum product demand in North America,

Figure 2.4
The Changing Composition Of Crude Oil Demand 1970 - 1987



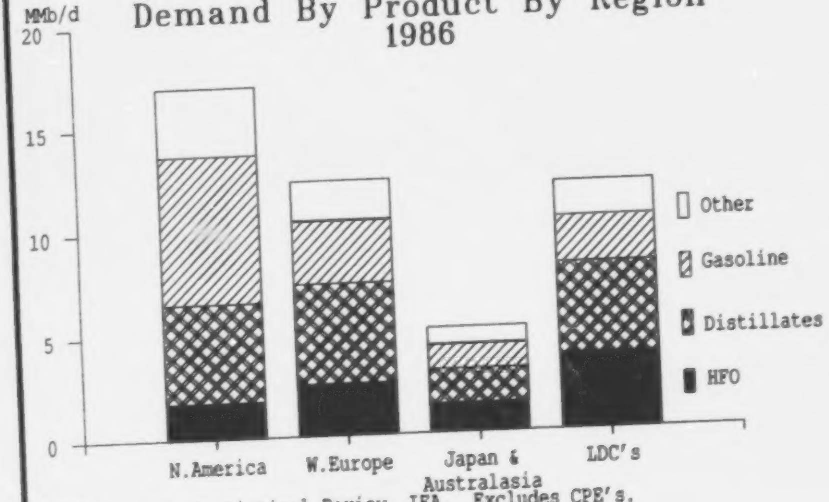
SOURCE: International Energy Annual, IEA. Excludes CPE's.

Figure 2.5
World Crude Oil Demand By Region
1967 - 1988



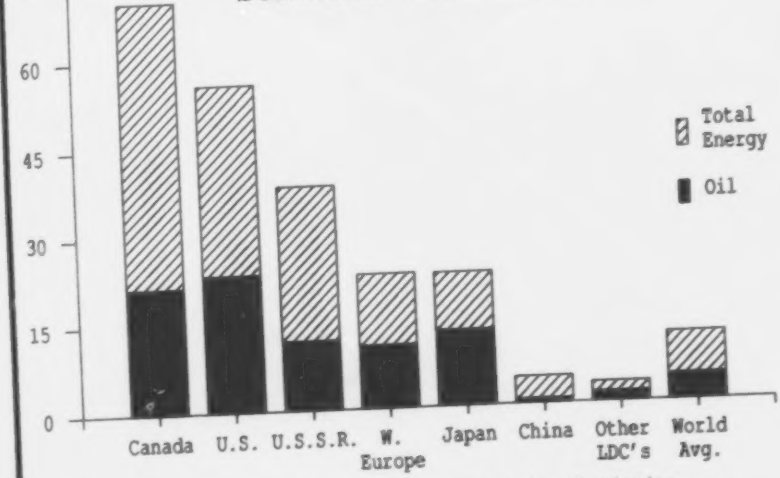
SOURCE: B.P. Statistical Review, IEA.
Excludes CPE's. 1988 forecast.

Figure 2.6
Demand By Product By Region
1986



SOURCE: B.P. Statistical Review, IEA. Excludes CPE's.

Figure 2.7
Per Capita Energy Consumption
Selected Nations, 1986



SOURCE: B.P. Statistical Review, U.N. Population Statistics.

accounting for 42 percent of total oil consumption, compared to an average of less than 22 percent in other non-CPE regions. The U.S. gasoline market, which consumes almost 7 MMb/d of crude oil equivalent, is by far the largest single petroleum product market in the world. European product markets are focussed more on middle distillates, reflecting a greater reliance on light fuel oils for home heating and diesel fuel for transportation. Heavy fuel oil plays a major role in Japan and the LDCs, where heavy industry is still primarily dependent on oil as a source of energy. Close to a third of total regional crude oil demand is accounted for by heavy fuel oil in Japan and the Third World, compared to roughly 20 percent in Europe and less than 10 percent in North America.

These differences in the product-by-product composition of crude oil demand will affect the responsiveness of demand in the various regions to changes in the price of oil and other variables. But these influences are interwoven in a complex, unpredictable, and often contradictory fashion that makes it difficult to ascertain the net impact. On the one hand, for example, we would expect oil demand to be the least price-sensitive in North America, given the heavy reliance on gasoline which does not generally face competition from substitute fuels. On the other hand, the ready availability of cheap substitute fuels (hydro, coal and natural gas), together with the popularity of dual-fuel power systems in the U.S. industrial sector, means that fuel switching in North America may be faster and more significant than in other parts of the world. Which of these two opposing tendencies might be more important is difficult to predict.

2.2.3 The Changing Relationship Between Oil Demand and Economic Growth

A final factor that has frustrated attempts to accurately predict the changing level of crude oil demand over the past 15 years has been the complex and unstable relationship between oil consumption and economic growth. As noted above, growth in Gross Domestic Product (GDP) was the primary determinant of crude oil demand in the period prior to 1973, when the world economy was expanding rapidly and crude oil prices were low and stable. It was also mentioned that the nature of economic growth in Third World countries partially explains why, since 1973, oil demand in that region has grown more quickly and consistently than in the rest of the world, and has tended to be more concentrated at the heavier end of the product spectrum.

There is no doubt that per capita energy consumption varies directly with the level of national income (see Figure 2.7), although it is also affected by other variables, notably climate and the degree of urbanization.

The share of oil products within total per capita energy consumption, however, is less directly related to income levels. A region's dependence on oil for its energy needs depends obviously on the relative abundance of other energy resources in that region (witness Canada's low dependence on oil, thanks to the variety of alternative energy sources that were developed during the high oil price era).

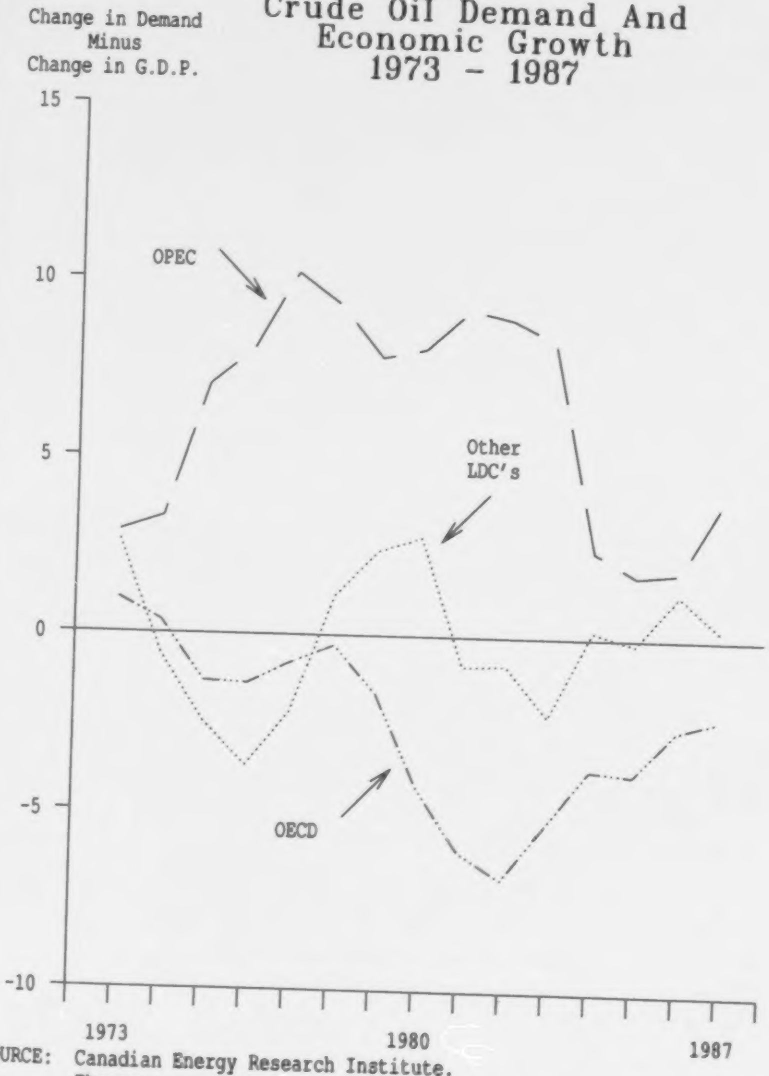
But there is some evidence to suggest that a nation's dependence on oil decreases as its economic wealth increases. The Third World countries depend on oil for a slightly greater share of their energy needs than other countries: 51 percent in 1986, versus 43 percent for the OECD countries. More importantly, the LDCs have not reduced their reliance on oil as much as other regions have, particularly when compared to the significant oil conservation achievements of Japan, Western Europe and Canada. The wealthier an economy is, the more able it is to pursue alternative energy options, and the more sophistication and flexibility it is likely to enjoy in its existing capital stock in order to respond quickly to changing energy markets. Moreover, the changes in the structure of the economy that accompany economic growth, with more emphasis on services and high-tech industry, and the relative decline of traditional "smokestack" industries, also act to reduce the oil intensity of economic growth in the more advanced regions.

So while oil demand is likely to increase as an economy expands, empirical evidence suggests that oil demand will not increase as fast as GDP (in other words, that the income elasticity of crude oil demand is positive but less than one). If true, this would mark a significant change from the pre-1973 era, when oil demand grew virtually in tandem with, or even faster than, the economy. Figure 2.8 plots the difference between the annual change in oil demand and annual economic growth over the past 15 years. If this difference is greater than zero, it means that oil demand is growing faster than the economy. If it is less than zero, it means that growth in oil demand is not keeping pace with economic growth, and the economy is becoming less oil intensive. The cyclical pattern of Figure 2.8 shows that oil-intensity has varied inversely with oil prices, and that conservation has been most intense following the sharp price increases of 1973-1974 and 1979-1980. But the over-all downward trend of oil intensity also suggests that the structural link between oil demand and economic growth has been weakened, so that even with relatively low oil prices in coming years we would not expect oil demand to increase at a pace similar to that of the 1960s and early 1970s.

2.3 Modelling World Oil Demand

The preceding section of this chapter described how world crude oil demand is comprised of various product and regional components. In other

Figure 2.8
Crude Oil Demand And Economic Growth
1973 - 1987



SOURCE: Canadian Energy Research Institute.
Three-year moving average. Includes domestic refining demand by OPEC countries.

words, global oil consumption is a heterogeneous, aggregate variable that encompasses the demand for different types of petroleum products in different parts of the world. This complex structure makes it very difficult for oil market analysts to interpret, explain, and predict oil demand behaviour. This section of the chapter will describe some of these difficulties and discuss a variety of methods that have been used by researchers in their attempts to model world oil demand.

2.3.1 Crude Oil Demand is a Derived Demand

With the exception of certain non-energy petroleum products, crude oil is not consumed for its own sake. Rather, the demand for crude oil is ultimately determined by the decisions of individual energy consumers, each desiring the services provided by the consumption of a refined petroleum product in a particular energy-using process. For example, some 7 MMb/d--close to 15 percent of non-CPE oil consumption--is consumed because of the desire of U.S. consumers for transportation services. They satisfy this desire by purchasing gasoline, which is used in automobiles, airplanes, and other transport equipment. A similar process explains the demand for other refined petroleum products in other parts of the world.

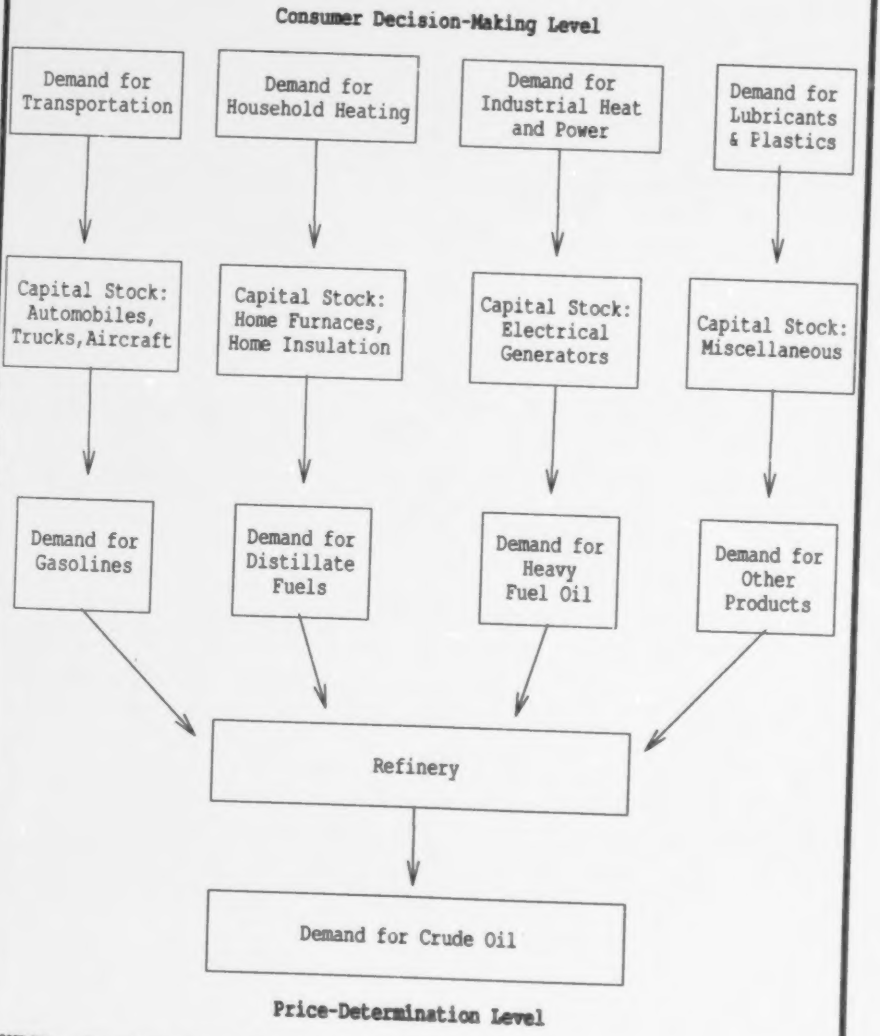
The problem that this poses for modelling world oil demand is illustrated in Figure 2.9. Final demand is based on the consumer purchase of the service ultimately provided by a refined product. The price of the refined product, the consumer's income, and the type of energy-using equipment in place are all inputs to that decision. The consumer's demand for energy services ultimately translates into a demand for crude oil, which interacts with the forces of crude oil supply to determine world oil prices. But there are numerous intervening factors between the consumer's demand decision and the determination of oil prices on the world market.

Before the impact of a change in oil prices on world demand can be ascertained, therefore, three distinct questions must be answered:

(i) What is the product and regional composition of oil demand?

As was mentioned above, certain refined products (such as heavy fuel oil) are more price sensitive than others (such as gasoline), due to the relative availability of close substitutes. A product slate weighted more towards these price-elastic products will therefore be more responsive to price changes than one that is based primarily on inelastic products.

Figure 2.9
Crude Oil Demand


Consumer Decision-Making Level
Demand for Transportation
Demand for Household Heating
Demand for Industrial Heat and Power
Demand for Lubricants & Plastics
Capital Stock: Automobiles, Trucks, Aircraft
Capital Stock: Home Furnaces, Home Insulation
Capital Stock: Electrical Generators
Capital Stock: Miscellaneous
Demand for Gasolines
Demand for Distillate Fuels
Demand for Heavy Fuel Oil
Demand for Other Products
Refinery
Demand for Crude Oil
Price-Determination Level

SOURCE: Canadian Energy Research Institute.

The response of demand to changing oil prices will also depend on the economic characteristics of each particular consuming region. Where oil demand is concentrated in regions (such as the LDCs) which exhibit a more direct relationship between economic growth and oil demand, the effects of a price change will be less significant than in those regions where that relationship has been weakened.

(ii) What is the relationship between world crude oil prices and the final end-use price of each refined product?

The consumer's demand decision is based on the final price of the relevant refined product, which includes refining costs, distributor's margin, and taxes. The impact of a change in the price of oil on the final price of the refined product can be muted by these non-oil cost components.

For heavy fuel oil and bunkering oil, for example, a 10 percent change in oil prices will be matched by an almost equally large change in the price of the final product, since unit refining costs and taxes are typically very low for these products (see Figure 2.10). Given that the price responsiveness of these heavier products tends to be quite dynamic, a 10 percent change in oil prices could have a significant impact on demand.

In the case of gasoline, however, the cost of crude oil makes up a comparatively small portion of the end-use price, since both taxes and refining costs are high for this particular product. A 10 percent change in the oil price might therefore result in a change of 2 percent or less in the gasoline price faced by the consumer. And given that gasoline demand tends to be quite inelastic with respect to its own price, there may be virtually no impact on demand resulting from the initial 10 percent change in the price of oil.

To make this question of petroleum product pricing even more complicated, the method by which crude oil prices are translated into refined product prices is by no means constant. Refining and distribution costs will vary with market conditions, while taxes, of course, are dependent upon the volatile and unpredictable swings of public policy. Taxes on most petroleum products in most consuming regions were increased dramatically as a conservation incentive during the late 1970s and early 1980s. This accentuated the impact on end-use prices of the successive OPEC-inspired crude oil price shocks, and probably contributed greatly to the surprisingly large fall-off in oil consumption that was subsequently experienced.

With the oil price crash of 1986, however, changes in tax rates played the opposite role. In an effort to maintain tax revenue from sale of refined petroleum products, many OECD governments increased taxes on transportation fuels and some distillate fuel oils.[1] Taxes on industrial fuels

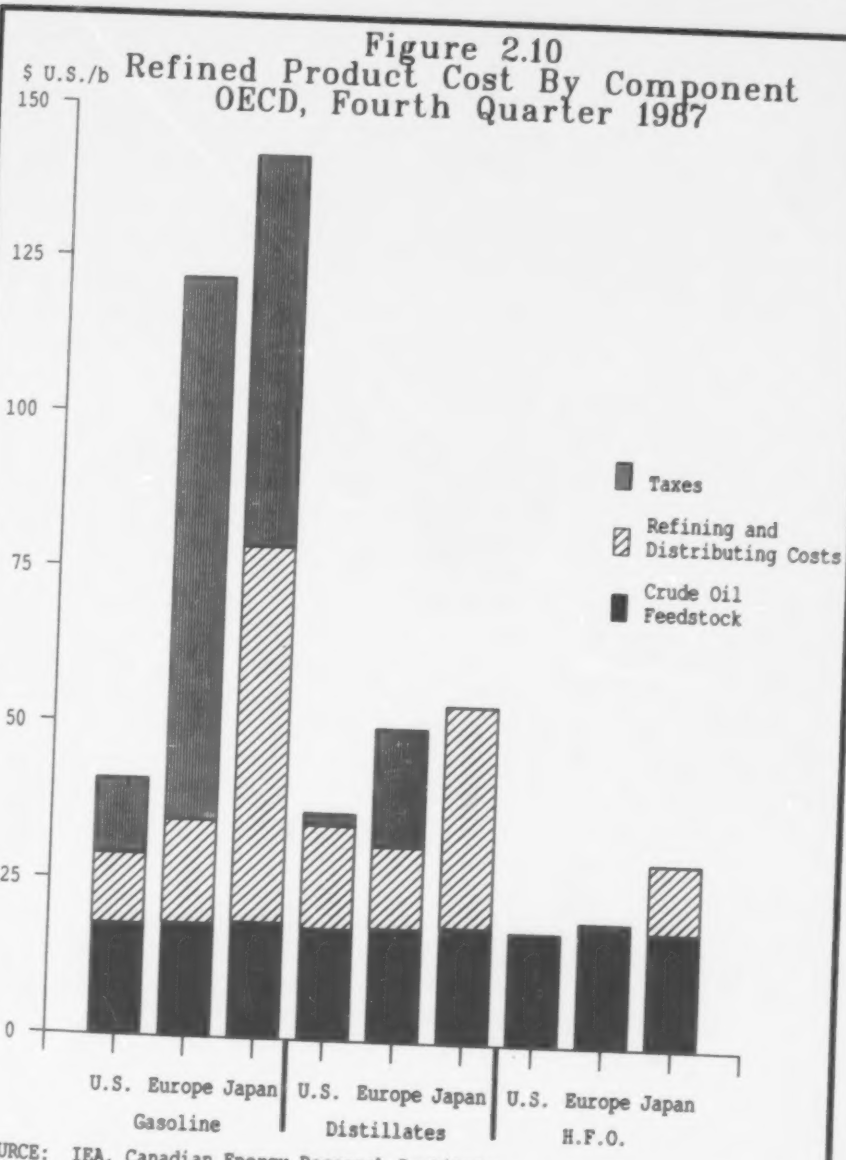


Figure 2.10
Refined Product Cost By Component
OECD, Fourth Quarter 1987

SOURCE: IEA, Canadian Energy Research Institute.
Europe refers to average of France, Germany, Italy, Spain and U.K.

were generally not increased, in the interests of maintaining international competitiveness in manufacturing industries. As a result, local-currency end-use gasoline prices in many OECD countries (notably Italy, Canada, and Australia) were virtually constant over the period 1985-1987, despite a fall of 35 percent or more in the local-currency cost of crude oil (see Figure 2.11). In this case, government policy greatly insulated the demand for certain refined products from the dramatic decrease in crude oil prices.

Another economic variable that must be considered here is the effect of fluctuating exchange rates. Energy consumers pay for the fuels they purchase in local currency units, and it is changes in that local-currency price that motivate consumers to alter the basket of energy services that they demand. The world price of oil, on the other hand, is determined by the interaction of supply and demand on international markets, and it is traditional for this price to be denominated in U.S. dollar terms. Thus, it is conceivable that local-currency refined product prices (in markets other than the U.S.) could vary purely as a result of fluctuating exchange rates, and not because of any change in international oil markets. Similarly, fluctuations in exchange rates might serve to offset or exaggerate fluctuations in world oil prices.

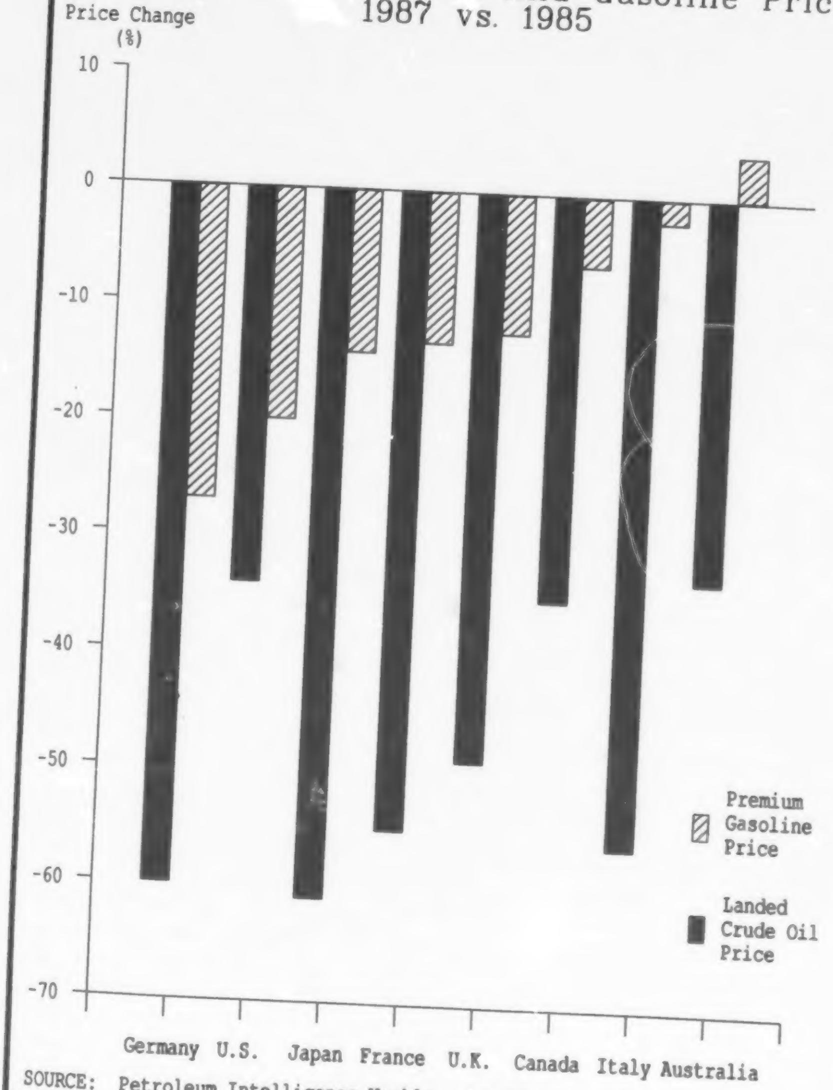
This has been the case recently due to the precipitous depreciation of the U.S. dollar relative to the European and Japanese currencies. The decline in the local-currency price of crude oil in Japan and several key European consuming nations has been much greater than the price saving enjoyed by U.S. consumers, since the oil price crash of 1986 has been amplified by the U.S. currency's depreciation. It is likely, therefore, that recent modest growth in crude oil demand in Europe and Japan would have been even less significant, were it not for this twofold decline in landed oil prices.

(iii) What is the nature of the energy-using capital stock, and how is it likely to change as a result of fluctuating oil prices?

If the energy-using machinery is capable of utilizing more than one type of fuel, then the demand response to a change in price will tend to be much more dramatic in the short run. In certain OECD countries, an increasing proportion of factories, electrical generating facilities, home furnaces, and even motor vehicles are dual-fuel capable. Where dual-fuel capacity exists, the prices of substitute fuels become important variables in determining demand for refined petroleum products, even in the short run.

In the North-eastern U.S., for example, a considerable portion of industrial heavy oil demand was lost in the early 1980s by factories and utilities switching to coal and natural gas. Many of these facilities retained the

Figure 2.11
Changes In Crude Oil And Gasoline Prices
1987 vs. 1985



SOURCE: Petroleum Intelligence Weekly. Prices in local currencies.

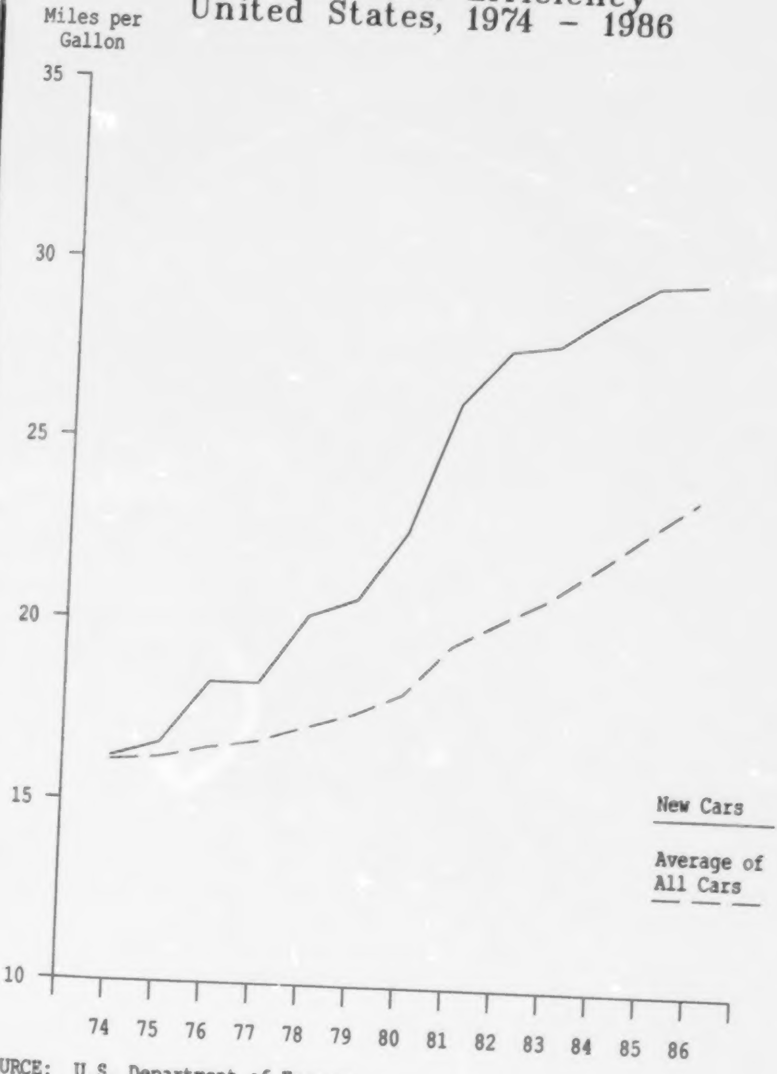
ability to switch back to oil immediately or on short notice. This dual-fuel capability accounted for much of the significant increase in U.S. heavy fuel oil consumption in the summer of 1986 (when oil prices dipped below $10 U.S. per barrel), and for the equally sharp drop in demand later that year when oil prices rebounded to levels that could no longer compete with substitute fuels.

This issue of short-term fuel switchability illustrates one mechanism by which the nature of the energy-consuming capital stock, in a static sense, can affect demand behaviour. An equally difficult modelling problem is posed by the dynamic process of longer-term adjustments in the capital stock, which may result from large fluctuations in relative energy prices. As described above, an initial change in the oil price will result in certain immediate demand effects as consumers, where possible, adjust their energy-consuming activity. Subsequently, longer-term effects are felt as consumers make changes to the stock of energy-consuming equipment. These longer-term results can significantly affect crude oil demand many years after the original motivating change in the price of oil.

For example, total gasoline consumption is the product of the total number of miles driven by consumers (an energy-consuming activity) and the average fuel efficiency of the fleet of vehicles (a characteristic of the energy-consuming equipment). The number of miles driven can respond immediately to a change in the price of oil. The fuel efficiency of new vehicles responded gradually but significantly to the oil price increases of the 1970s, as manufacturers introduced smaller cars with more efficient engines. The average fuel efficiency of all vehicles responded much more slowly, however, since only a small portion of the total fleet of vehicles is retired and replaced in any given year by more fuel-efficient new cars and trucks (see Figure 2.12).

There is no reason to expect that manufacturers will revert to the production of inefficient vehicles. Nevertheless, following the oil price crash of 1986 the average fuel efficiency of new vehicles seems to have reached a plateau, primarily because many consumers, influenced by current low oil prices, are purchasing larger automobiles than in previous years. The average fuel efficiency of the total vehicle fleet is continuing to increase, however, despite the fall in oil price. Why? New cars are not more efficient than the new cars of 2 or 3 years ago, but they are more efficient than the 10-year old cars that they are replacing. Thus, the average fuel efficiency of all vehicles on the road will continue to increase for several years, partially offsetting the impact on gasoline demand of consumers' willingness to drive greater distances. In this way, the demand response to current low prices is muted by the lingering effects of previous price increases.

Figure 2.12
Vehicle Fuel Efficiency
United States, 1974 - 1986



SOURCE: U.S. Department of Energy.

This example illustrates that the time lags involved in the full adjustment of oil demand to changes in world oil prices can dramatically interfere with any effort to forecast future demand trends. Similar scenarios can be developed for the other petroleum products and their corresponding energy-consuming capital equipment. These longer-term adjustments to the capital stock may serve to make consumption of a refined product more efficient (as in the case of gasoline described above), or they may serve to replace the demand for the refined product entirely with a demand for a substitute fuel (for example, the use of natural gas or electric furnaces in new or retrofitted homes). In the latter case, the price of the substitute fuel and its expected long-term relationship to the price of the competing petroleum product once again becomes an important input to the consumer's demand decision.

A final note must be added here concerning the role of consumer expectations. An investment in new energy-consuming machinery is usually made on the basis of a 5- to 25-year time horizon. Consumers will not make price-induced adjustments to their energy-using capital stock unless they believe that the energy market conditions that justify the investment will be more or less permanent over the useful life of the capital good. Therefore, even dramatic short-term fluctuations in the price of oil may not initiate the longer-term capital adjustments described above, if consumers suspect that the "spike" in oil prices is only temporary.

This issue of consumer expectations helps to explain the dramatic response of world oil demand to the second oil price shock of 1979-1980. The second huge increase in oil prices in 5 years triggered a widespread conviction that oil prices were locked in a long-term, upward spiral. The logical response to this expectation was that the sooner investments could be made in oil-conserving and oil-substituting transportation, heating and power generating equipment, the sooner they would be paid off.

Likewise, consumer expectations have played a major role in dampening the demand response to the 1986 decline in world oil prices. Real oil prices are lower than at any time since 1974, and in certain cases are cheaper on a Btu-equivalent basis than substitute fuels. Yet consumers will not invest heavily in oil-intensive capital equipment unless they are convinced that low oil prices are here to stay. Most analysts, however, appear to expect exactly the opposite--namely, that real oil prices will start to recover strongly sometime in the 1990s--so it is unlikely that the recent oil price weakness will lead to any fundamental re-orientation towards oil on the part of most energy consumers.

2.3.2 Choice of a Modelling Framework

The preceding section described three of the most important issues that complicate the study of world oil demand:

(i) the fact that demand behaviour varies between different refined petroleum products and between different regions;

(ii) the indirect relationship between world crude oil prices (denominated in U.S. dollars) and end-use product prices (denominated in local currency units, and including taxes, refining costs, and distributors' margins); and

(iii) the time lags associated with price-induced changes to the energy-consuming capital stock, whereby large oil price fluctuations can affect demand for many subsequent years, and whereby the price of substitute fuels can have a significant impact on oil demand, especially in the longer-term.

Given these problems, what is the most appropriate modelling framework that should be used, both to interpret and estimate historical demand trends, as well as to predict future levels of oil demand on the basis of expected oil prices and GDP trends? While a wide variety of approaches have been used to model world oil demand, they can be roughly divided into three broad schools of thought:

(i) reduced-form estimation;

(ii) top-down estimation; and

(iii) bottom-up estimation.

Of these three general approaches, reduced-form modelling is the most straightforward. A reduced-form model of world oil demand simply estimates oil demand directly, on the basis of crude oil or average refined product prices and some measure of economic growth, perhaps modified by a time-lag structure.[2] This approach studies oil demand at the aggregate level, rather than breaking oil demand into its different product components. It therefore abstracts from the problem that consumer behaviour, in responding to changes in prices and GDP, will vary according to the type of refined product being consumed. Some reduced-form models have disaggregated oil demand on the basis of consuming region, allowing for the consideration of differences in demand characteristics between LDCs and OECD countries, for example. Others have also incorporated the prices of substitute fuels into their equations, accounting with limited success for the process of interfuel competition and substitution.

The major benefit of the reduced-form approach is its simplicity and, correspondingly, the limited amount of data that is required to run such a model. Its major shortcoming, however, is its lack of flexibility in dealing with the effects of changes in the product composition of oil demand. For example, world crude oil demand proved relatively elastic with respect to price in the early 1980s. One of the most important factors explaining that elasticity was the dramatic decline in the use of heavy fuel oil by industries and utilities in most OECD countries. Now that heavier products make up a much smaller portion of total oil demand, future oil conservation and substitution in these sectors of the economy will have a less dramatic impact on aggregate oil consumption. The reduced-form model has no means of accounting for this composition effect.

The second approach to modelling oil demand--the top-down methodology--starts from the principle that consumers do not demand a refined petroleum product for its own sake, but rather for the energy services that it provides (see Figure 2.9). The appropriate starting point, then, is to estimate total energy demand in a particular country or a particular sector of the economy, and then to subsequently determine the share of crude oil in total energy demand on the basis of relative fuel prices, the nature of the energy-using capital stock, and other variables.[3] These models are very sophisticated in their ability to interpret the effects of interfuel substitution and even capital-energy substitution, particularly when they estimate petroleum demand at the sectoral level (i.e., demand in the industrial sector, residential sector, etc.). Top-down modellers have also been at the leading edge of new mathematical and econometric techniques--such as translog cost functions and Box-Jenkins regressions--which have helped to improve the accuracy and the insight of historical demand studies.

But these strengths of the top-down modelling approach are offset by weaknesses and data requirements that make them inappropriate for the purposes of forecasting global crude oil demand. The highly sophisticated treatment of interfuel competition, for example, is accompanied by an immense requirement for supplementary data. The model requires data on the final prices of all competing fuels and the nature of the capital stock in each sector of the economy. So, while top-down models have been applied quite successfully in explaining and interpreting oil demand in a particular sector of an advanced economy like the U.S., consistent data at the required degree of detail is simply unavailable on a worldwide basis. More importantly, it is impossible for an analyst to predict capital stock indices, relative fuel prices, and the other data inputs required by the top-down models, in order to forecast world oil demand. Therefore, most top-down econometric studies have been limited to estimating historical oil demand, rather than attempting to predict the future course of world oil consumption.

Finally, the very sophistication of the econometric techniques used by the top-down models means that their results tend to be totally dependent on the precise mathematical formulations adopted. A small change in the form of a demand equation can typically lead to large and fundamental changes in the implied values of price and income elasticities. Since the econometric debates between the various advocates of the top-down approach have yet to be conclusively resolved, it becomes difficult and risky for a modeller to choose one particular top-down formulation over another.

This leaves the third approach to modelling world oil demand--bottom-up estimation--as the most practical compromise between the detail of the top-down approach and the workability of the reduced-form models. The bottom-up approach starts by estimating the demand for each of the major types of refined petroleum products, based on the end-use price of that product, GDP trends, and occasionally upon supplementary variables (such as measures of capital stock or of competing fuel prices). Total oil demand is then calculated by aggregating the demand for each product.[4] Product demand equations can differ between regions to account for the specific characteristics of local energy demand. Interfuel competition can be integrated into the model directly, by including the prices of substitute fuels in the demand equations, or indirectly, by capturing the effects of interfuel competition in the price and income elasticities specified for each refined product. The details of the bottom-up world oil demand model that was developed for this study are described in the following section.

2.4 A Description of CERI's World Oil Demand Model

The preceding section discussed the key problems encountered in attempting to interpret and forecast world oil demand. It also summarized and briefly evaluated the various methodologies that have been employed by oil demand models. This final section describes the structure of CERI's demand model, together with its major strengths, weaknesses, and some key results.

2.4.1 The Structure of the Model

Of the three major modelling approaches described above, we have selected the "bottom-up" methodology for the demand component of the CERI World Oil Market model. Firstly, the model divides the world into seven consuming regions:

(i) Canada;

(ii) U.S.;

(iii) Western Europe;

(iv) Japan, Australia and New Zealand;

(v) Less developed countries, excluding OPEC members;

(vi) OPEC countries; and

(vii) Centrally planned economies.[5]

Within each of these consuming regions, product demand equations have been specified for each of four different groupings of refined petroleum products:

(i) gasoline (including aviation fuels);

(ii) middle distillates (including automotive diesel fuel);

(iii) heavy fuel oils; and

(iv) other products (including non-energy products, refinery fuel, and losses).

A total of 28 product demand equations are therefore required to run the demand model: four product types in each of the seven consuming regions. Each equation predicts demand for a particular product in a particular region. The resulting volumes (in barrels of oil equivalent) are summed across products to obtain regional oil demand estimates, and then aggregated across regions to obtain total world oil consumption.

The specific form of the demand equations used by the model is the log-linear, "constant elasticity" demand function that has become widely accepted in the econometric literature. In this equation, demand for any particular refined product will change in response to an initial change in any of three variables:[6]

(i) the price of the refined product;

(ii) the GDP of the consuming region; and

(iii) previous levels of consumption of the refined product.

When run separately from the supply component of the World Oil Market model, the demand model requires price and GDP data to be supplied exogenously. The third input variable--previous levels of product consumption--is calculated endogenously, by referring back to the previous year's estimate of product demand (see Figure 2.13).

Corresponding to these three variables, which act as inputs to the demand function, are three constants or parameters, which determine the relative impact that each input variable will have on end-use demand. The first two parameters are the straightforward price and income elasticities, which determine how demand will react in the short term to changes in product price and GDP.

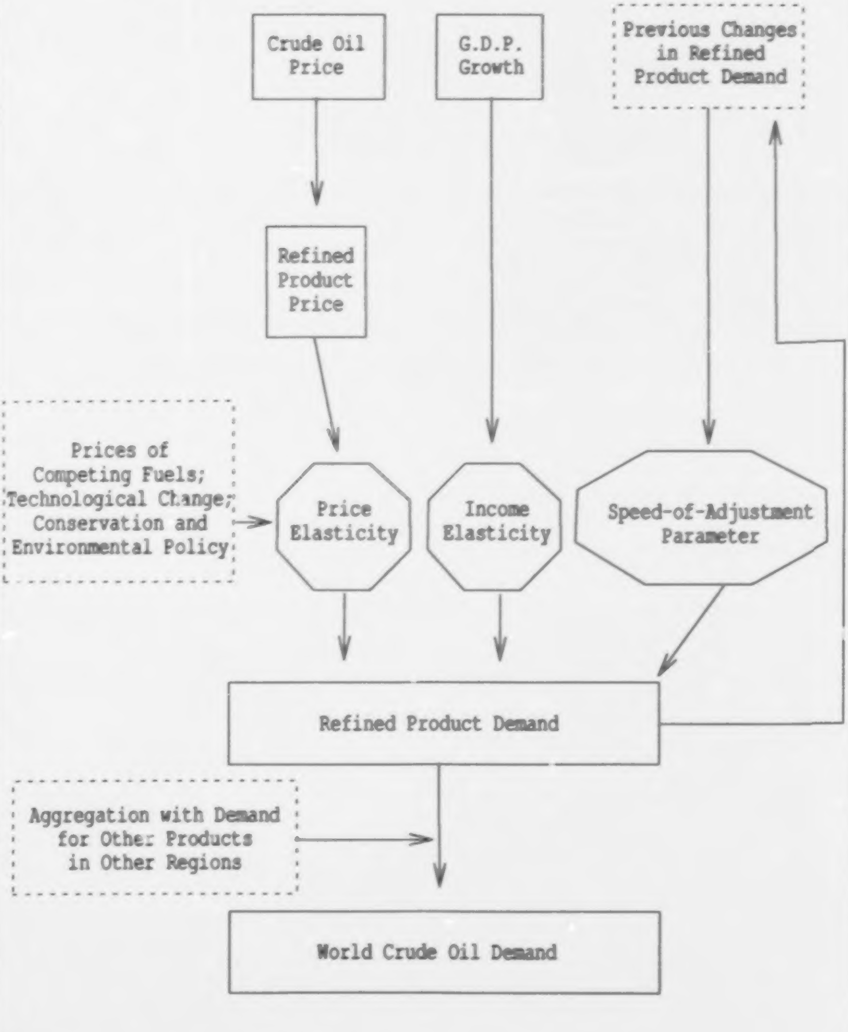
The third parameter is known as a "speed-of-adjustment" factor, and warrants a brief explanation. This factor is designed to account for the lagged impact of price changes on the energy-using capital stock, as explained in Section 2.3.1 above. The equation adopts a "partial adjustment" approach to incorporating these lagged effects. It is postulated that because of the time required to fully adjust energy-consuming machinery, the actual change in product demand that occurs in a given year will only be a fraction of the change that would be required to reach the consumers' desired or optimal level of consumption. The rest of the adjustment is achieved in later years, as consumers act to adjust equipment and plant in response to the change in energy prices.

The speed-of-adjustment parameter falls between zero and one. A value of 0.5, for example, implies that 50 percent of the desired response in demand to a change in price or national income will occur in the current year; the rest will be spread out over subsequent years. The closer the parameter is to one, the faster is the demand adjustment to price or income shocks, and the less important is the lagged effect of these shocks in future years. Conversely, the closer the parameter is to zero, the slower is the immediate demand adjustment, and the more important will be the future aftershocks of current-year fluctuations in the oil price and GDP.

In addition to this basic estimation of product demand, the model includes a second set of equations which calculate refined product prices for each product in each region, on the basis of a single representative world crude oil price. These equations have been constructed on the basis of historical levels of taxes, refining costs, and transportation and distribution expenses in each of the consuming regions.[7]

In this fashion, the demand component of CERI's World Oil Market model can predict the demand for four sets of refined petroleum products in seven different regions on the basis of just two exogenous inputs: a world oil price, and regional GDP forecasts. The demand model can be operated independently by inputting both an oil price forecast and GDP

Figure 2.13
Structure Of The Demand Model


Crude Oil Price
G.D.P. Growth
Previous Changes in Refined Product Demand
Refined Product Price
Prices of Competing Fuels; Technological Change; Conservation and Environmental Policy
Price Elasticity
Income Elasticity
Speed-of-Adjustment Parameter
Refined Product Demand
Aggregation with Demand for Other Products in Other Regions
World Crude Oil Demand

SOURCE: Canadian Energy Research Institute.

growth paths. Alternatively, when the demand and supply components of the CERI model are run simultaneously, then the world oil price is determined by the intersection of demand and supply, and the GDP forecast is the only exogenous input required by the demand side of the model.[8]

2.4.2 Strengths and Weaknesses of the Model

One of the major strengths of the demand model is its disaggregated approach to the specific regional and product characteristics of world oil demand. By estimating demand separately for each product category in each region, the model can take into account the peculiarities of demand behaviour that influence demand at the end-use level. Despite this relatively complex level of detail, however, the model has quite modest requirements for information input. As described above, only oil price data and regional GDP forecasts are required to produce a world demand forecast, disaggregated by region and by product.

While freedom from heavy data requirements is a significant benefit of this approach, it is a serious over-simplification to suggest that oil prices and national income are the only two variables which can affect world crude oil demand. For example, the demand model (as presently constructed) offers no explicit consideration of the process of interfuel competition and substitution. As described earlier, the prices of substitute fuels can have a significant impact on oil demand, both in the short term, if dual-fuel capacity exists, and in the longer run where it is possible to invest in non-oil-burning capital equipment. The top-down interfuel competition models described in Section 2.3.2 offer a better interpretation of this substitution process, but they require extremely detailed data inputs for variables such as relative fuel prices and changes in the capital stock--data that would be impossible to assemble and forecast on a consistent, worldwide basis.

The best option available for considering the effects of interfuel competition is to have them reflected indirectly by the model, in the form of the price and income elasticities and speed-of-adjustment parameters (as indicated in Figure 2.13). Where a refined petroleum product is subject to intense interfuel competition (as is heavy fuel oil, for example), then the corresponding price elasticity parameter for that product should be set relatively high, reflecting the process of fuel substitution that would accentuate the demand response to a change in price. And where significant volumes of dual-fuel capacity exist, the speed-of-adjustment factor would also be increased, reflecting the ability of energy consumers to switch quickly from one fuel to another.

This is an imperfect method of considering the effects of interfuel competition and substitution, most importantly because it implicitly assumes that oil prices are independent of other energy prices (that is, that a fall or increase in oil prices will not necessarily be matched by parallel movements in other energy prices). But given the impossibility of exogenously predicting future movements in competing energy prices, this is the most acceptable approach to the problem of modelling the world oil market available at present. Future improvements and extensions to the CERI demand model will attempt to improve on this treatment of the relationship between competing energy forms.

A similar approach can be taken in accounting for some of the many other variables which impact on world petroleum consumption. For example, where future technological change is expected to lead to more efficient and/or less oil-intensive energy consuming machinery, then the income elasticity for the corresponding petroleum product can be reduced. This would reflect the transition to lower levels of oil intensity as an economy advances. Environmental concerns might also be considered by the model in a similar fashion: reduce the income elasticity of demand for products which are environmentally sensitive (such as high-sulphur, heavier products), resulting in a gradual shift away from reliance on these fuels in tandem with economic growth.

The three parameters that are used by each product demand equation, therefore, indirectly reflect the myriad of influences other than price and GDP which help to determine oil demand: interfuel substitution, technological change, public policy and others. But this flexibility in turn underlines another weakness of the demand model, namely that its results are very dependent on the values that are adopted for each of the three parameters (price elasticity, income elasticity and the speed-of-adjustment factor).

We have chosen our parameter estimates on the basis of an extensive survey of the many econometric studies of refined product demand in various regions of the world. But these studies are by no means complete. Product demand in the less developed and centrally planned economies, in particular, has not been subject to a great deal of investigation. Even where petroleum product demand has been studied in immense detail (such as gasoline demand in OECD countries), there is seldom a widespread agreement regarding the value of price and income elasticities and other parameters. For the purposes of this study, then, parameter estimates have been used that are representative of the results of econometric research (see Appendix A for further detail).

A note is warranted at this point on the use of constant price- and income-elasticities in a long-term forecasting exercise such as this. First, the elasticity values used in the model were estimated over a period of time (1965-1984, on average) characterized by large crude oil price increases. It is questionable whether the response of crude oil demand to price declines (both speed of adjustment and magnitude) will be asymmetric to that exhibited in response to historic price increases. Second, the magnitude of response of crude oil demand to a price change in the short term may be greater than in the past (due to greater fuel substitution capability) or less (due to exhaustion of readily available conservation and efficiency initiatives, in the case of a price increase).

Therefore, the analyst is left in a quandary, knowing that future demand response to crude oil price changes will likely not be the same as in the past, but unsure as to the direction in which to adjust the response parameters used in the model. Future improvements to the model will include a more intensive investigation of the likely values of these parameters and how they differ between regions and between products. More importantly, since the "final word" will never be written on the "correct" way to estimate price and income elasticities, it would be useful for the model to explicitly incorporate the uncertainty that surrounds the demand equation parameter estimates--perhaps by means of a Monte Carlo-type sampling procedure.

One further potential shortcoming of the model is that it presently has no mechanism for treating the effects of oil price changes asymmetrically--that is, the model considers the impact of a given price change on demand to be equal in magnitude, regardless of whether that price change is an increase or a decrease. There is a strong intuitive argument to suggest that the effect on demand of a price decrease will not be as great as the effect of a previous price increase of similar size, because of the fact that the theme of oil conservation has been permanently "built in" to both modern technology and consumers' attitudes. It has not been conclusively shown, however, that this muting of the demand response to falling prices should be reflected in price elasticities that are lower (in absolute terms) than those applied to price increases. Some demand models (such as the one used by the International Energy Agency) specify price elasticities that are lower for price decreases than price increases, but this approach is not yet widespread.[9]

While there are good reasons to believe that the effect on demand of lower prices will not be as dramatic as the effect of the sharp price increases of the 1970s, this does not automatically mean that price elasticities are therefore asymmetrical. Rather, there are other qualitative factors--all of which are theoretically consistent with symmetrical price elasticities--

which help to explain this somewhat sluggish demand response to recent price decreases. Two of these factors are particularly important:

(i) consumers expect that oil prices will rebound substantially in the near future, and therefore will not adjust their long-term energy strategies to become more reliant on oil; and

(ii) governments in many consuming countries have increased taxes on refined petroleum products, offsetting the decrease in crude oil feedstock costs.

Future versions of the model could be expanded to include some mechanism to account for this effective asymmetry in demand behaviour. Otherwise, the model is likely to modestly overestimate crude oil demand in those years (such as 1988) when the average world crude oil price falls.

2.4.3 Performance of the Model

The CERI World Oil Market model contains a demand component and a supply component. The two sides of the model are combined and run simultaneously, in order to derive a crude oil price forecast that balances supply and demand (see Chapters 4 and 5). Alternatively, the demand and supply components can be run independently, in each case using an exogenously specified price forecast as input data, to study the effects of different possible price projections on the two sides of the world oil market equation. In the following discussion, a sample forecast of world crude oil demand is presented (based on a plausible but not definitive crude oil price forecast), followed by an exposition of the sensitivity of that sample forecast to changes in oil prices, GDP paths, and the underlying price and income elasticities of refined product demand.

For the sake of discussion, we have assumed an illustrative forecast for the world price of crude oil. This price path is not a prediction, nor is it a "base case" (although it is not dissimilar to our reference case crude oil price scenario described in Chapter 4). Rather, it is simply a "test" forecast of crude oil prices that allows us to study the performance of the demand model. This forecast assumes that oil prices recover significantly by the end of this decade, followed by modest and steady increases in real prices through the 1990s.[10]

The demand model was used to estimate global crude oil consumption on the basis of this price forecast and on the GDP growth assumptions outlined in Appendix C. These results are described in Table 2.1. The model projects strong demand growth in 1988 of 2.0 percent--a response both to weak prices and to the lagged effects of growing demand in the immediately

TABLE 2.1

WORLD CRUDE OIL DEMAND TEST FORECAST

Year	Real World Oil Price ($U.S. 1987)	Annual Real Price Growth (%)	World Crude Oil Demand[a] (MMb/d)	Annual Demand Growth (%)
1987	18.70	-	48.6	-
1988	17.50	-6.4	49.6	2.0
1989	18.75	7.1	50.1	1.1
1990	19.45	3.7	50.5	0.8
1991	19.95	2.6	51.0	0.9
1992	20.50	2.8	51.4	0.9
1993	21.20	3.4	51.8	0.8
1994	21.90	3.3	52.2	0.7
1995	22.75	3.9	52.6	0.7
1996	23.66	4.0	52.9	0.7
1997	24.40	3.1	53.3	0.7
1998	25.20	3.3	53.7	0.8
1999	26.20	4.0	54.1	0.7
2000	27.00	3.1	54.5	0.8
Average		**2.9**		**0.9**

SOURCE: Canadian Energy Research Institute.

[a] Excluding CPEs.

preceding years. Demand growth moderates in subsequent years, thanks to the recovery in real prices. Oil demand increases at slightly less than 1 percent per annum through the rest of the century, with the consequences of steady price increases more than offset by the beneficial impact of continued economic growth.

Average demand growth rates for each consuming region and each group of refined products are provided in Table 2.2. As expected, gasoline exhibits the strongest demand growth, since there are fewer competing fuels, and since a given increase in the crude oil price translates into a smaller end-use price increase for gasoline than for other products (due to higher taxes and refining costs). Heavy fuel oil consumption is essentially stagnant, with the continued decline in OECD regions almost offset by growth in Third World consumption. On a regional basis, demand growth is strongest in the Third World--particularly in the OPEC countries, where governments are likely to continue to keep domestic prices lower than in the rest of the world. OECD demand grows at a more modest annual rate of about 0.4 percent, led by the U.S. with its burgeoning gasoline consumption. Crude oil consumption in the centrally planned economies (where GDP growth is the determining variable) is forecast to increase by about 1.5 percent per annum.

Once an illustrative demand forecast has been made, the demand model can be tested to determine its sensitivity to a variety of changes in its assumptions. First and foremost, we want to analyze the demand model's sensitivity to price changes. The forecast described above showed that demand growth is restrained but not reversed by modest but steady increases in real oil prices. As an alternative scenario, the demand model was fed three constant real price paths, in which the oil price was set at $15, $20, and $25 per barrel (in $1987 U.S.) in 1988 and held there until the end of the forecast horizon. The results of this sensitivity study are shown in Figure 2.14. A sudden price increase to $25 per barrel results in a 5-year decline in demand, as oil consumption adjusts fully to the higher level of prices. World demand subsequently recovers on the strength of global economic growth, reaching some 52 MMb/d by 2000. A price increase to $20 per barrel in 1988 results in 2 to 3 years of stagnant demand, followed by steady demand growth averaging 1.4 percent per year over the 13-year forecast period. Not surprisingly, a decrease in price to $15 per barrel results in an immediate acceleration in demand, with annual growth rates reaching 2.5 percent over the forecast period.

The demand model is almost as sensitive to changes in the underlying GDP growth rate assumptions. Figure 2.15 illustrates the basic test forecast described in Table 2.1 above, using our base case GDP growth rate assumptions (shown in Appendix C). Also shown in Figure 2.15 are the world

TABLE 2.2

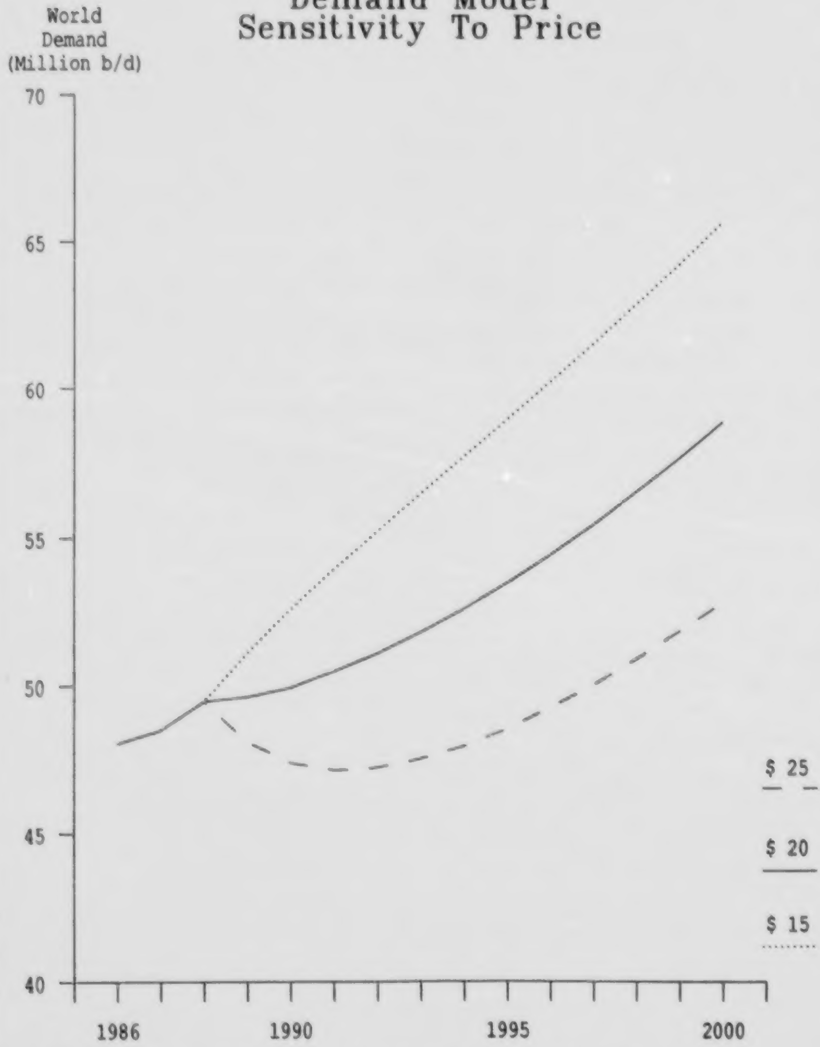
WORLD CRUDE OIL DEMAND
TEST FORECAST - DISAGGREGATION

Category	Average Annual Increase in Demand, 1987-2000 (%)
Gasoline[a]	1.5
Middle Distillates[a]	0.5
Heavy Fuel Oil[a]	-0.1
Other[a]	1.2
Canada	0.3
U.S.	0.6
Western Europe	0.1
Japan & Australia	0.4
LDCs	1.9
OPEC	2.5
CPEs	1.5
World Total[a]	**0.9**

SOURCE: Canadian Energy Research Institute.

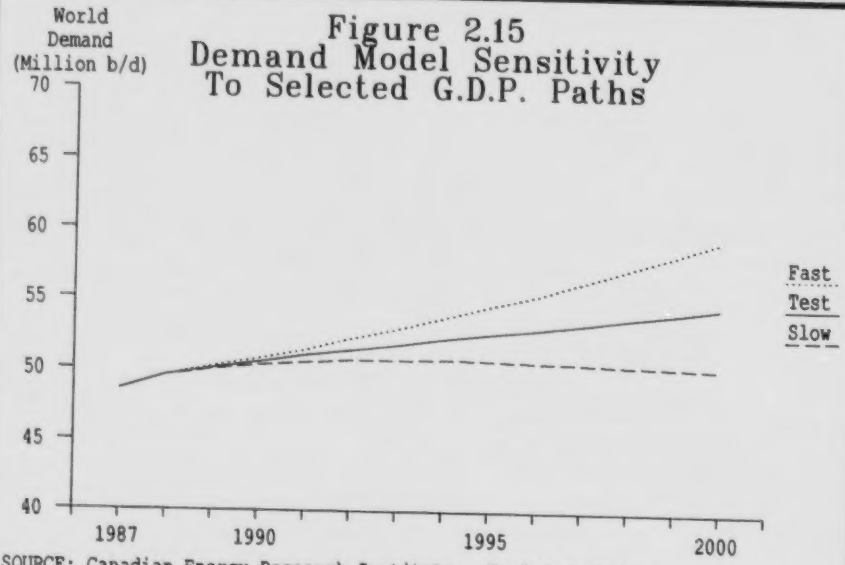
[a] Excluding CPEs.

Figure 2.14
Demand Model
Sensitivity To Price



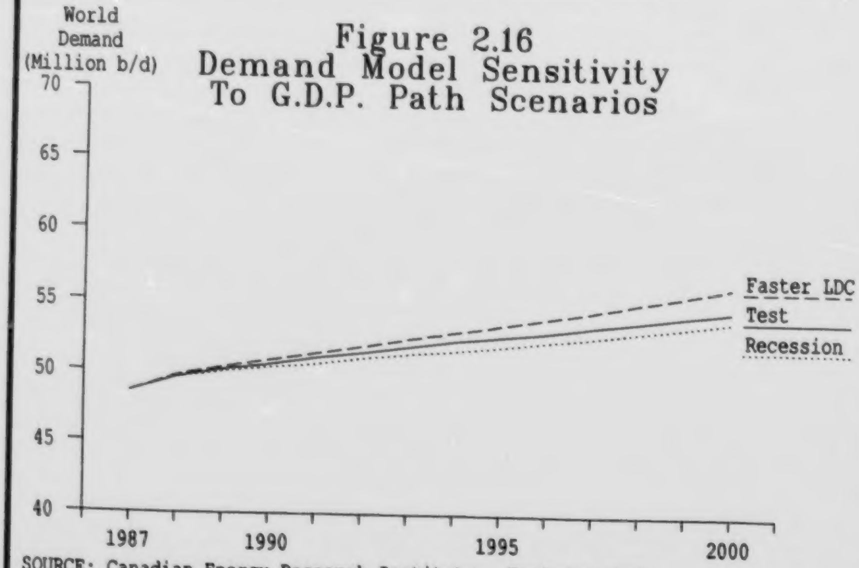
SOURCE: Canadian Energy Research Institute. Excludes CPE's.

Figure 2.15
Demand Model Sensitivity To Selected G.D.P. Paths



SOURCE: Canadian Energy Research Institute. Excludes CPE's.

Figure 2.16
Demand Model Sensitivity To G.D.P. Path Scenarios



SOURCE: Canadian Energy Research Institute. Excludes CPE's.

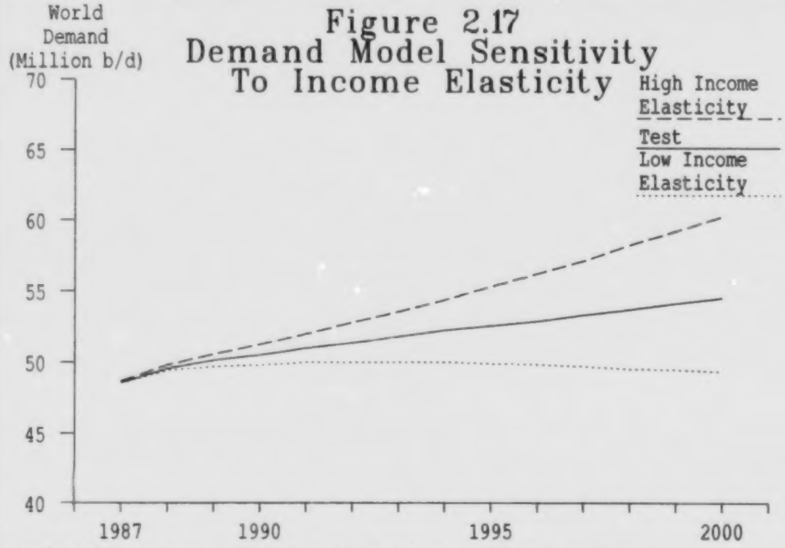


Figure 2.17
Demand Model Sensitivity
To Income Elasticity

SOURCE: Canadian Energy Research Institute. Excludes CPE's.

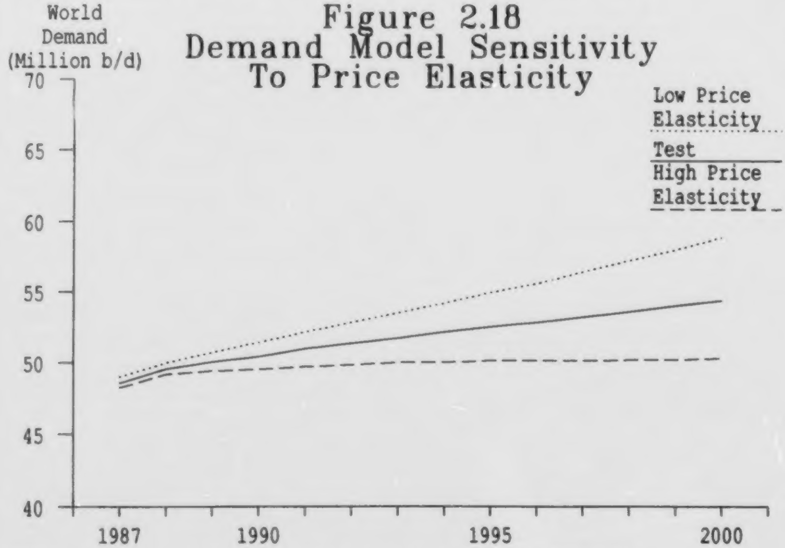


Figure 2.18
Demand Model Sensitivity
To Price Elasticity

SOURCE: Canadian Energy Research Institute. Excludes CPE's.

demand paths calculated by the model on the basis of a 50 percent increase and a 50 percent decrease, respectively, in the base case GDP growth rates (but assuming the same illustrative price forecast). In each case, adjusting the GDP forecasts by 50 percent results in a change in forecast world demand in the year 2000 of approximately 5 MMb/d. Note also that in the case of very slow GDP growth, sluggish economic expansion is just sufficient to offset the negative effects of increasing real prices, so that aggregate world demand stays virtually constant at just less than 50 MMb/d.

The problem with the above simulation is that it is not likely that the base case GDP forecast will be off by as much as 50 percent. Figure 2.16 shows the sensitivity of world demand to two more likely GDP scenarios: a faster rate of economic growth in the LDCs (5.0 percent per annum, versus 3.5 percent in the base case), and a severe recession in 1989-1990 in the OECD countries (where GDP growth is assumed to equal zero in both years). The demand paths corresponding to both scenarios do not differ as dramatically from the test case as in the previous simulation. Nevertheless, either scenario could be expected to have a moderate impact on world prices--particularly the case of faster LDC growth, which would add an extra 2 MMb/d to world crude oil consumption by 2000.

Finally, it must be acknowledged that the output of the demand model is extremely sensitive to the assumed values of price and income elasticities. In a worst-case situation, suppose that the price or income elasticities listed in Appendix A could be off by as much as 50 percent. Figures 2.17 and 2.18 reveal what a tremendous impact this would have on the final demand forecast. Each scenario is based on the same oil price and GDP forecasts as the sample demand forecast of Table 2.1. A higher price elasticity results in lower demand estimates, since future price increases are more effective in restraining demand growth.[11] If both sets of elasticities were erroneous in a complementary direction (that is, the price elasticities were too low and the income elasticities were too high, or vice versa), then the effect on the demand forecast would be compounded.

Based on a careful analysis of the econometric work done to date, it is unlikely that our elasticity estimates are incorrect to such a degree. But given that there is no consensus regarding the precise degree to which modern crude oil demand is responsive to changes in price and income, differences in the elasticity estimates adopted by various world oil demand models will continue to explain why these models arrive at such divergent forecasts of future global oil consumption.

Footnotes

[1] A detailed description of these changes is included in the International Energy Agency's review, Energy Policies and Programmes for IEA Countries (Paris: International Energy Agency, 1986 and 1987).

[2] See, for example, Chris Hope and Phil Gaskell, "The Competitive Price of Oil," Energy Economics, Oct. 1985; L. Lorentsen and K. Roland, "World Oil Market Model," Energy Journal, Jan. 1986; Scott B. Brown, "Aggregate Oil Consumption," Energy Economics, Jan. 1983; and Peter M. Hutchinson and Dale Ferrone, "Estimating Crude Oil Demand," Review of Business and Economic Research, Fall 1977.

[3] See, for example, M. P. G. Pepper, "Box-Jenkins Forecasts of Over-all Energy Demand," Energy Economics, July 1985; Robert S. Pindyck, "Inter-fuel Substitution and Demand in Industry," Review of Economics and Statistics, May 1979; Albert L. Danielson, "Demand Functions for Oil, Coal, and Gas," Review of Business and Economic Research, Winter 1977-78; and G. B. Nicolaou, "Petroleum Versus Other Fuels in the U.K.," Applied Economics, June 1977.

[4] Characteristic examples of the bottom-up approach include P. Rice and V. I. K. Smith, "An Econometric Model of the Petroleum Industry," Journal of Econometrics, Nov. 1977; and M. Kennedy, "An Economic Model of the World Oil Market," The Bell Journal of Economics and Management Science, Autumn 1974.

[5] The centrally planned economies present special difficulties for modelling oil demand, due to a lack of historical price and consumption data, and to the nature of economic decision-making in a planned economy. The greatest problem faced in modelling CPE oil demand is the relationship between consumption and price.

It is clear that world oil prices will have an important indirect effect on consumption--even in a planned economy where prices are set by the government--but it is difficult to interpret and simulate how that effect would be felt. The most important link between world oil prices and CPE oil demand is exercised through CPE net crude oil exports. If world prices are high, then so is the opportunity cost of domestic consumption--representing the hard-currency revenue lost because of foregone exports. This might provide a stimulus for domestic oil conservation. On the other hand, if world prices are low, centrally planned economies might have to increase their net exports in order to meet a fixed hard-currency earnings target. Low world oil prices, therefore, might also be consistent with reductions in domestic CPE consumption, in order to free up more volumes for export. Even in those planned economies which are not net exporters of crude oil (such as most of the East European countries), low administratively-set domestic refined product prices are not necessarily associated with high rates of oil demand growth, since the planned economy is supply-constrained and prices do not play the same role in balancing supply and demand as they do in a market economy.

So while price is still an important determinant of oil demand in the CPEs, it is impossible to capture this complex relationship between price and demand in a world-scale demand model. For the purposes of this study, therefore, we have set price elasticities to zero in the CPE demand equations, so that CPE oil consumption is driven by GDP growth alone. See Appendix A for details of the demand equation parameters that we have chosen for the CPE region. Finally, Section 4.4.6 of Chapter 4 describes how the CPE demand calculation in the model can be over-ridden by an exogenous assumption regarding the level of CPE net exports.

[6] For details of the equation specification, please see Appendix A.

[7] For more details on the estimated relationship between the world crude oil price and regional refined product prices, please see Appendix B.

[8] Regional GDP forecasts provided by Project LINK are used for the first five years of the model forecast, with long-term averages used for subsequent years. See Appendix C for details.

[9] See George Kowalski, "Energy Market Developments and Outlook for the 1990s," paper presented to the Norwegian IAEE Energy Conference, Oslo, September 1987.

[10] Exactly the same price forecast is used to test the supply side of the World Oil Market model in Chapter 3 below.

[11] This differs from the findings of a recent study by R. N. Cooper, W. W. Hogan, D. W. Jorgenson, and B. Mossavar-Rahmani, Lower Oil Prices: Mapping the Impact (Cambridge, Mass.: Harvard Energy and Environmental Policy Center, 1988), which forecasts a possible return to $30 oil prices by 1990, on the basis of enhanced price elasticity. The Harvard study sees prices being driven up by a surge in demand, which is the delayed but elastic response to the 1986 fall in oil prices. In the CERI model, higher price elasticities restrain the rebound in demand as prices increase, preventing a rapid run-up in the price. It is unclear in the Harvard model why the price elasticity of demand does not produce a sharp decrease in demand once prices reach $30 and higher.

Chapter 3

WORLD OIL SUPPLY

3.1 Introduction[1]

The last two decades have witnessed a dramatic transition and restructuring of the supply side of the world oil market. From a market dominated by large international oil companies and characterized by low, stable prices in the 1960s, a dominant cartel has emerged, has used its market power to raise world oil prices by twentyfold, and has seen this market power subsequently eroded as soaring prices stimulated a tremendous supply response in the non-OPEC countries and a concurrent contraction in world oil demand.

The underlying determinants of this complex evolution have been varied. Economic forces, political events and government policy initiatives have all played important roles in determining the path of the world oil market. However, it has become apparent that the most resilient factor underlying these changes has been economic forces. In raising prices to unprecedented levels, OPEC ultimately sowed the seeds of its own demise. World oil demand responded almost immediately as oil-importing countries plunged into economic recession and initiated vigorous conservation programs. Crude oil supplies outside of OPEC were slow in responding, but the ultimate response was dramatic, as higher prices contributed vast sums to the exploration and development budgets of oil companies around the world.

This chapter of the study is intended to achieve three primary goals. First, we provide a brief overview of the critical events, key trends and underlying determinants that history has revealed about the supply of crude oil. This discussion is contained in the chapter's first section. Second, we present the supply side component of CERI's integrated World Oil Market model. Accordingly, the second section of the chapter applies some of the lessons which history has taught us, to describe the conceptual structure of the analytical framework developed to evaluate future crude oil supplies. And finally, we present some representative results to illustrate the sensitivity of the world oil supply model to various assumptions. This is accomplished in the final section which describes the application of the supply model to the analysis of potential time paths of world oil production under a variety of price and resource assumptions.

3.2 The History of World Oil Supply

In 1970, OPEC had yet to emerge as a cohesive cartel. The posted price of Saudi Light stood at about $1.80 per barrel and had remained at that level in nominal terms since 1960.[2] World crude oil production totaled slightly over 45.5 MMb/d and petroleum product consumption was in the midst of a prolonged surge that had seen world oil demand increase by 50 percent over 5 years. OPEC member countries lifted over 50 percent of world supplies that year, with production exceeding 23 MMb/d while the OECD countries contributed the second largest share at 11.4 MMb/d. The two groups of countries who would see their production expand the most over the next 16 years--the developing nations (LDCs) and the centrally planned economies (CPEs)--contributed the smallest shares at 2.6 and 7.9 MMb/d, respectively.

Since 1967, a series of political events had taken place which would later have an enormous impact on the development of the world oil market:

- The Suez Canal was closed in 1967 because of the Arab-Israeli war;
- In the same year supplies from Nigeria, a previously reliable source of oil, had ceased due to the Biafran civil war;
- In May 1970, Syria blocked the Trans-Arabian pipeline carrying 500 thousand barrels per day (Mb/d) of crude oil destined for European markets; and
- Mohammar Qaddafi became the political leader of Libya.

Previous attempts by OPEC to raise oil prices had met with stiff resistance from international oil companies backed by legal clauses in concession agreements that gave them the sole right of pricing. At best, OPEC had managed to stave off decreases in the nominal price of oil. Soon after his ascension to power in 1970, Qaddafi provided other OPEC countries with an inkling of the latent market power a cohesive cartel might exert on the world oil market. He demanded that one of the more vulnerable oil companies--Occidental Petroleum Inc., an independent oil company that was heavily dependent on Libyan production to supply its European refineries--provide a larger per barrel share of its oil revenue to the Libyan government. After failing to obtain guaranteed supplies from Exxon or Shell to replace its Libyan losses, Occidental was forced to capitulate to this demand. Other companies in Libya shortly followed suit. Eventually, the major oil companies offered similar terms to all the other OPEC member countries.

The recognition of this newfound bargaining power spurred OPEC members to push for further benefits between 1970 and 1973. New agreements with oil companies resulted in a price increase of 30 cents per barrel in 1971 with a further increase of 20 cents due in 1975. Unsatisfied with these agreements, on October 16, 1973 OPEC imposed a unilateral increase in the marker crude (Arabian 34° API) price from $3.01 to $5.12 per barrel.

Before this price increase could take effect, another political event was to have a decisive impact on the world oil market. Arab producers decided to reduce their oil production by 5 percent and place an embargo against the U.S. and the Netherlands, to show their dissatisfaction with the two countries' support of Israel in the 1973 Arab-Israeli war. In the now tighter market, auction prices of more than $20 per barrel were being quoted on the world oil market. This provided OPEC with the impetus to further increase prices from $5.12 to $11.65 per barrel in December 1973.

Thus, heading into the mid-1970s, world oil markets were being forced to deal with the reality of a cartel that had illustrated its effectiveness by quadrupling world oil prices in a 4-month period. However, growth in world oil consumption continued to be robust. Between 1970 and 1978, despite an increase in nominal oil prices from $1.80 to $12.70 per barrel, the demand for OPEC oil expanded by over 25 percent from 23.7 MMb/d to 29.8 MMb/d, while total world oil production increased 32 percent to 60.3 MMb/d (see Figure 3.1). Although OECD production had edged up slightly over this period, from 11.4 to 12.0 MMb/d, its share of total production had declined significantly from 25 to 20 percent. The LDC's and the CPE's enjoyed the largest production increases, with average daily output growing 73 percent to 4.5 MMb/d and 75 percent to 13.9 MMb/d, respectively.

Higher oil prices also had a significant impact on drilling activity levels and world oil reserves, as illustrated in Figures 3.2 and 3.3. From a low of 172 million feet drilled in 1971, drilling activity increased 80 percent to 308 million feet drilled in 1978. However, most of this increased activity was occurring in the OECD countries--primarily the U.S., where the total footage drilled increased from 138 to 243 million feet. Despite the intensified drilling activity, OECD proven reserves declined from 56 to 50 billion barrels. In contrast, the footage drilled in the LDC and OPEC countries increased only moderately--from 11.7 and 13.8 million feet to 14.3 and 18.2 million feet, respectively--while proven reserves grew considerably, from 18 and 407 billion barrels to 51 and 443 billion barrels, respectively.

While not readily transparent, the above trends reveal a significant difference in the oil supplies of the OECD and LDC countries. Despite only an 18 percent increase in drilling footage between 1970 and 1978,

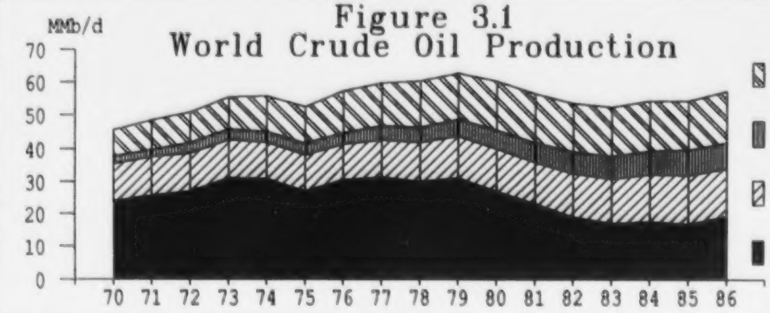


Figure 3.1
World Crude Oil Production

SOURCE: Canadian Energy Research Institute, World Oil Magazine.

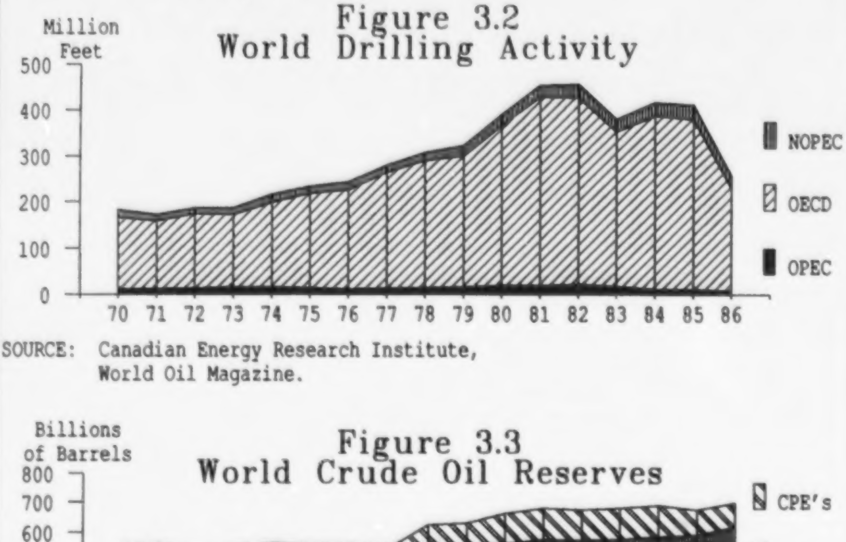


Figure 3.2
World Drilling Activity

SOURCE: Canadian Energy Research Institute, World Oil Magazine.

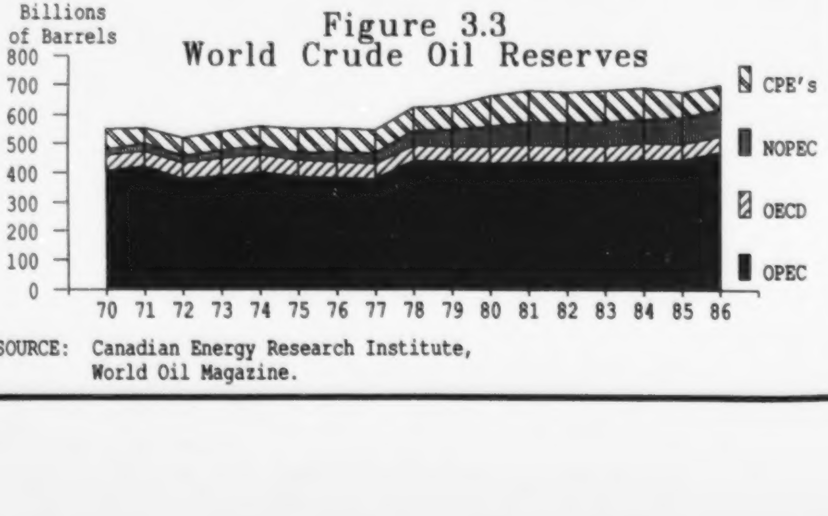


Figure 3.3
World Crude Oil Reserves

SOURCE: Canadian Energy Research Institute, World Oil Magazine.

production and reserves in the LDCs countries grew 75 and 185 percent, respectively. In the OECD countries, the reverse was true--drilling footage increased 78 percent while production expanded only 5 percent and reserves actually declined by 12 percent. This reflects the much higher returns to drilling available in the less intensively explored LDC countries and the relatively advanced state of depletion in the OECD countries--again, primarily in the U.S. Were it not for the dramatic increase in drilling, it is highly unlikely that the U.S. would have been able to stave off significant production declines over the last decade.

World oil markets entered a softer phase between 1975 and 1978. World crude oil production had slumped to 52.8 MMb/d in 1975, due mainly to economic recession in the OECD countries. Some OPEC countries--particularly Saudi Arabia, Kuwait and Iran--successfully decreased production levels to defend prices during this period. By 1976, the economies of the OECD countries had entered into a recovery phase and world production had rebounded to 57.4 MMb/d.

At this time, it became evident that OPEC was aligning itself into two factions--each with distinctly different revenue requirements and demographic characteristics. Each faction also held sharply different perceptions about what constituted an optimal pricing strategy. One group, led by Saudi Arabia, Kuwait and the United Arab Emirates--the moderates--favoured constant or slowly rising real prices to support further demand growth and to limit increases in non-OPEC production. This group was generally characterized by enormous per capita reserves and hence their interests focussed on the maintenance of a long-term, stable price level consistent with a long-term profit maximization strategy. The other group, led by Iran, Iraq, Libya and Algeria--the price hawks--argued for significant short-term price increases to compensate for the higher inflation rates then prevailing in the OECD countries. Countries in this group generally had smaller per capita reserves, were very dependent on oil revenue to finance ambitious government spending plans and were thus much less interested in any long-term, stable pricing strategy.

These conflicting objectives were evident in the difficulties that OPEC member countries experienced in reaching pricing agreements between 1975 and 1978. In the December 1976 meeting, the price hawks argued that prices should be increased 15 to 25 percent, while the moderates proposed an increase of 5 percent. Both sides insisted on their positions and a two-tiered pricing structure emerged. Saudi Arabia and the UAE increased their official prices by 5 percent effective January 1, 1978 while the rest of OPEC decided to increase prices by 15 percent (10 percent effective January 1 and 5 percent effective July 1). Saudi Arabia, which had surplus production capacity of about 2 MMb/d at this time, then decided to push production up to the capacity limit. It took them three months to reach this goal, and resulted in a significant decrease in the sale of Iran and Kuwait's heavy crudes (which are very similar to the Saudi crudes). The resulting compromise saw Saudi Arabia and the UAE agree to increase their prices by 5 percent while the other countries agreed to forego the scheduled increase of 5 percent in July.

The pre-eminent position of Saudi Arabia within the cartel had thus been illustrated and in 1978, when they proposed a price freeze, the other OPEC countries agreed not to disagree with them. At that time, the price freeze had considerable merit. OPEC was entering 1978 in a rather disadvantageous position. Oil companies had built up large stocks in the fourth quarter of 1977 which they started to draw down in the first quarter of 1978, reducing the call on OPEC production from 31.6 to 28.5 MMb/d over the two quarters. Increases in non-OPEC production from Alaska and the North Sea had created an oil glut, causing some OPEC countries (mainly African light oil producers) to introduce special discounts for oil companies to lift their oil. And finally, the U.S. dollar was depreciating rapidly, leading to a significant decline in the purchasing power of OPEC's oil revenue.

All indicators at this point seemed to suggest that the world oil market had entered a fairly stable equilibrium. Between 1974 and 1978, oil prices had remained virtually constant in real terms. During this period, world crude oil production increased only 9 percent, roughly equivalent to a single years' growth in the 1960s. OPEC production had remained relatively constant, varying between a low of 27.2 MMb/d in 1975 and a high of 31.3 MMb/d in 1977. As Shiek Yamani, Saudi Oil Minister between 1962 and 1987, reflected in a 1986 address:

> This balanced supply/demand situation at (the then) prevailing prices signalled that additional price increases of sizeable magnitude would disturb the balance by generating a decline in consumption coupled with an oversupply situation.[3]

However, in 1979 the pervasive influence of politics on the world oil market was again illustrated, presenting the cartel with an opportunity they could hardly refuse. In January 1978, Iranian oil production came to a virtual standstill because of strikes in the oil fields. Combined with the increased demand by importing countries, who were already apprehensive about their supply security, and the cessation of oil supplies from the major oil companies to smaller independents, the reduction in Iranian output created a scramble for oil supplies on the spot market. Spot prices soared, exceeding $40 per barrel as panicky buyers bid up prices.

It is worth noting, however, that these prices were not reflective of market fundamentals. As illustrated in Table 3.1, OPEC production in the first quarter of 1979 was actually greater than in the first quarter of 1978 by over 800 Mb/d. In addition, non-OPEC supplies increased by about 1 MMb/d in the first half of 1979. And finally, over the preceding several years the demand for OPEC oil during the first quarter had been less than in later quarters because of normally occurring stock drawdowns in the oil-importing countries. Regardless of the supply disruption within Iran, it is apparent now that there was more than enough oil on the world oil market to meet demand during the first half of 1979. Thus, the skyrocketing spot prices were more attributable to the pyschology of the marketplace and panic on the part of buyers than to any fundamental change in the supply/demand balance.

TABLE 3.1

WORLD OIL SUPPLIES DURING THE IRANIAN CRISIS
(MMb/d)

	Saudia Arabia	Iran	Total OPEC	Non-OPEC	Total[a] World
1978	8.3	5.2	29.9	20.1	50.0
1Q	8.0	5.5	28.5	19.6	48.1
2Q	7.6	5.6	29.1	20.0	49.1
3Q	7.6	5.8	30.4	20.3	50.7
4Q	10.0	3.8	31.4	20.7	52.1
1979	9.5	3.1	30.8	21.4	52.2
1Q	9.8	1.2	29.3	20.9	50.2
2Q	8.8	3.9	30.9	21.5	52.4
3Q	9.8	3.8	31.8	21.4	53.2
4Q	9.8	3.4	31.3	21.7	53.0
1980	10.0	1.5	27.2	22.2	53.5

SOURCE: Petroleum Economist, Various Issues.

[a]Excluding CPEs.

Nevertheless, it seemed natural for the OPEC countries to take advantage of the situation by raising their official prices in line with spot prices. During 1980, continuous "leapfrogging" by the cartel countries led to an increase in the average OPEC marker crude price from $26 per barrel at the beginning of the year to $36 per barrel by the end of the year. As shown in Table 3.2, Saudi Arabia's official prices consistently lagged those of the other countries. When Saudi Arabia raised its crude prices in an attempt to

TABLE 3.2

OFFICIAL OPEC SELLING PRICES
($U.S. per barrel, nominal dollars)

Date		Saudi Arabia (34° API)	Kuwait (35° API)	Iran (34° API)	Iraq (37° API)	Libya (36° API)
1977	Jan. 1	12.09	12.69	12.81	12.58	13.24
1979	Jan. 1	13.34	13.33	13.45	13.21	14.03
	April 1	14.55	16.34	16.57	15.60	17.60
	July 1	18.00	19.99	22.00	19.96	22.80
	Oct. 1	18.00	21.93	23.50	21.96	25.57
	Nov. 1	24.00	26.00	28.50	23.96	25.57
1980	Jan. 1	26.00	28.00	31.00	27.96	34.02
	May 1	28.00	32.00	35.37	31.96	36.30
1981	Jan. 1	32.00	36.00	37.00	35.96	40.30
	Nov. 1	34.00	34.01	34.60	33.96	36.80
1982	Jan. 1	34.00	34.01	34.20	33.46	35.60
1983	Feb. 1	30.00	30.01	28.00	28.46	29.20

SOURCE: OPEC Annual Statistical Bulletin, 1984.

close the gap, the rest of the cartel followed suit, thereby preserving the gap. In an attempt to impose price harmony on the cartel, Saudi Arabia produced at near record levels throughout 1980. The response of other cartel member countries, however, was to cut production rather than forego price increases.

The market reaction in 1980 to yet another (and more serious) supply disruption stands in sharp contrast to that following the 1979 Iranian crisis. In September, war broke out between Iran and Iraq, causing the loss of nearly 4 MMb/d of production from the two countries. This time, however, increased production by the Gulf producers (led by Saudi Arabia), lower demand for OPEC oil, and the presence of high oil stocks in the importing countries combined to avert a panic on the world oil market. As a result, spot prices did not appreciate significantly although, as noted above, the sequence of events did allow OPEC to continue to increase their official prices.

Thus at the end of 1980, OPEC's official prices were three times as high as they were at the end of 1978, essentially destroying the balance that had existed in the world oil market. The OECD countries, led by the U.S. and U.K., were plunging into economic recession, resulting in a sharp contraction in world oil demand which was exacerbated by the impact of vigourous energy conservation measures. Between 1979 and 1985, total world oil consumption fell by almost 5.5 MMb/d or 9 percent.

OPEC's market share was also being squeezed by the emergence of nearly 5.9 MMb/d of additional production from non-OPEC sources of supply. Higher prices had sparked another surge in drilling activity around the world. Footage drilled in the OECD countries--again primarily in the U.S.--increased to a peak of nearly 410 million feet, compared to 284 million feet in 1979, before declining slightly to 371 million feet in 1985. This allowed these countries to increase combined production by 2.1 MMb/d--primarily from the North Sea region. As was the case between 1970 and 1978, drilling activity in the LDC countries was less responsive to higher prices, with the total footage drilled only increasing from 20.6 to 29.6 million feet drilled per year over the same period. However, these increased activity levels as before generated a significant supply response, adding over 3 MMb/d to total world production.

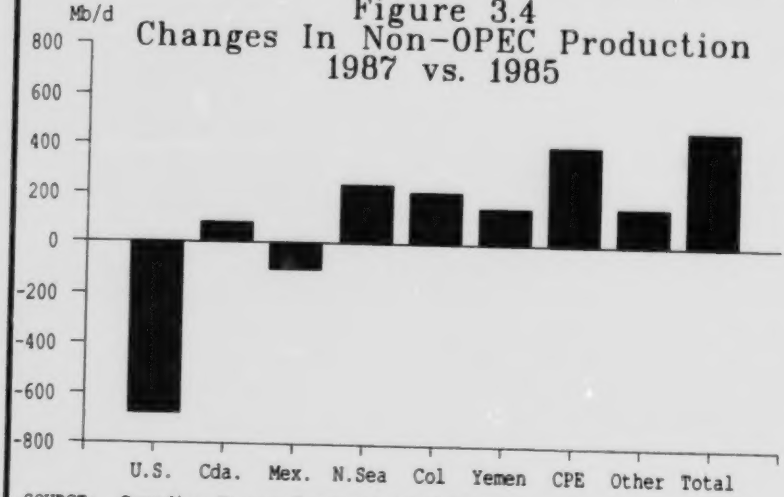
This relentless pressure from both sides of the marketplace caused total OPEC production to plunge from 30.9 to 16.9 MMb/d between 1979 and 1985. The stress on the cartel surfaced in 1983 when--for the first time since its formation--OPEC agreed to reduce official prices, from $34 to $29 per barrel. At this time, Saudi Arabia officially became OPEC's swing producer by reducing production to support the new world price structure. However, this did little to stem the inexorable decline in the demand for OPEC oil. In their attempt to balance world supply and demand at the prevailing price level, the Saudi's saw their production slide from a peak of 9.6 MMb/d in 1980 to just over 2.3 MMb/d in August 1985.

The tremendous reduction in revenue resulting from both volume and price reductions made Saudi Arabia's role as swing producer untenable. In mid-1985 the Saudi's decided they could no longer adhere to a fixed price system and joined other OPEC countries in market-based (or netback) pricing.[4] The objective was to force the cartel to cooperate in a new policy involving a sharing of prorationed output in support of official prices. The use of netback contracts increased rapidly within OPEC and the effect on world oil prices was delayed but dramatic. Saudi Arabia managed to increase its production to close to 5 MMb/d in 1986, but at great cost. The world oil price deteriorated dramatically, falling to as low as $9 per barrel in July 1986. This was lower than the prices prevailing in 1974 in nominal terms, and markedly lower in real terms.

The price crash has had varying degrees of impact on the oil producing nations of the world. Drilling footage in the OECD fell 70 percent--once again primarily in the U.S--while it fell only 20 percent in the LDC countries. Over 700 Mb/d were lost in the U.S., due largely to the shut-in of as many as 100,000 high cost, low production stripper wells. However, total non-OPEC supply outside of the U.S. proved to be quite resilient, increasing by some 1.2 MMb/d and more than offsetting the U.S. decline (see Figure 3.4). Nevertheless, the rate of growth in total non-OPEC output outside the U.S. was cut in half by the price crash, from 7 percent per annum over the period 1982-1985 to an average of 3.6 percent per annum during 1986 and 1987.

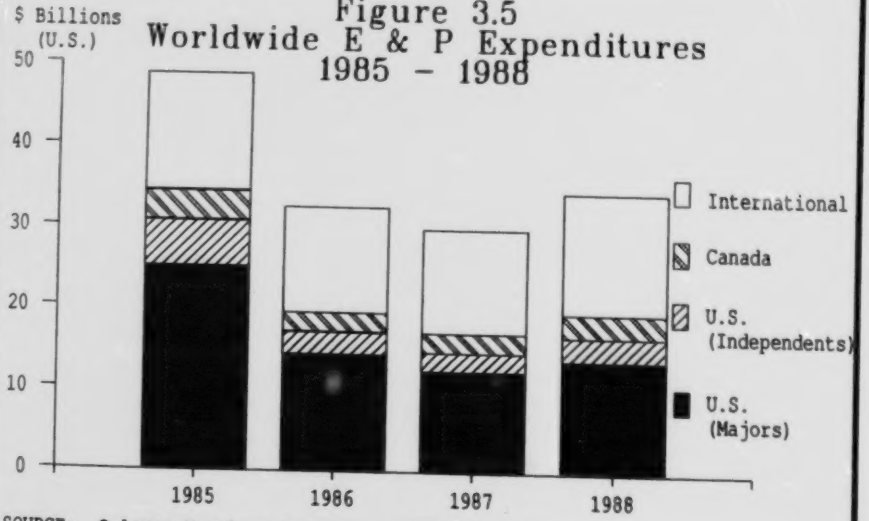
Evidence of the redirection of industry attention away from North America to basins in the LDC countries, Europe and Australia is provided in Figure 3.5. Planned spending outside of North America is expected to be higher in 1988 ($14.8 billion) than it was in 1985 ($14.4 billion). This contrasts sharply with a drop of over 50 percent in total U.S. spending over the same period and a more modest 20 percent drop in Canadian exploration and production budgets. Indeed, even with the prospect of a flat $18 per barrel price, the combination of lower costs for drilling and service work and adjustments to fiscal regimes in most countries have altered the economics of exploration and development so that investment overseas is almost as attractive today as it was in 1985. As a result, crude oil production outside of North America is expected by most market analysts to continue to increase over the short-term.

Figure 3.4
Changes In Non-OPEC Production
1987 vs. 1985



SOURCE: Canadian Energy Research Institute.

Figure 3.5
Worldwide E & P Expenditures
1985 - 1988



SOURCE: Salomon Brothers Surveys. 1987 data estimated; 1988 data planned. Includes expenditures by 207 largest firms.

3.3 Modelling World Oil Supply

In order to evaluate the longer-term potential for crude oil supplies, an analytical framework is required to account for the various technical and economic linkages and interrelationships in an internally consistent manner. An essential element of the CERI World Oil Market model is the assessment of future world oil supplies as a function of world oil prices. This section of the study describes the conceptual development and structure of the analytical framework comprising the supply side component of the integrated model.

The crude oil supply chain, stretching from exploration to discovery and development to production, is an extremely complex process. A tremendous degree of uncertainty accompanies each stage of the supply chain, particularly with regard to the volume of undiscovered resources, the returns to drilling effort and the pace of development. The complexity of constructing an analytical framework to describe this process is compounded by the inferior quality of supply side data in most countries, by the fact that drilling and production decisions are made by both private and national oil companies whose budget constraints and financial objectives may differ considerably, and by the heterogeneity of fiscal regimes around the world. Political events or policy changes, which are neither generalized nor predictable, will also have a significant impact on world production levels.

Attempting to model world oil supply is therefore a nearly impossible task unless certain simplifying assumptions are made regarding key real world relationships. In developing the methodological approach used in the World Oil Market model, the following elements were considered essential. First, the 15-year time horizon adopted for the market projections necessitated that the supply model embody the principal determinants of long-term crude oil supply. These are:

- How much of the resource remains to be discovered?
- What portion of this potential will be found and produced at various price levels?

Second, because oil is an exhaustible resource, the supply model must incorporate empirical evidence that the achievement of constant future reserves additions will generally require greater exploratory effort as the resource base is depleted (i.e., diminishing returns to exploration effort). Moreover, the quality of future reserves additions is also likely to decline because of the likelihood that oil will increasingly be found in smaller pools, at greater depths with poorer producing characteristics, and in more remote and hostile locations. However, offsetting these upward pressures on future supply costs will be the increased knowledge gained by explorationists in terms of both geology and seismic technology, and of producers in terms of improved technologies to increase the recovery of oil-in-place. How these two opposing forces--advancing technical and geological knowledge and a declining resource base--interact in the future, although highly uncertain, will be an important determinant of future oil supplies and prices.

Finally, the supply model must portray the existing market structure of oil producers and producing nations. It must also have the flexibility to examine the impact of potential changes in this market structure on the world oil market. Today, oil producers belong to one of two broad categories:

- The cartel core, which consists of those OPEC countries who could be considered "price-makers," in that they can determine prices by their own ability and willingness to balance world oil supplies with demand. In all definitions, the core will consist of those countries with prodigious oil resources and excess productive capacity per capita, such as Saudi Arabia and Kuwait. Under some scenarios, depending on the hypothesized degree of cartel unity, it may consist of all the OPEC member countries or some subset; and
- The competitive fringe, which consists of those producing countries which appear to act as price-takers in the sense that the petroleum companies (whether nationalized or private) take the world price as given, and make supply decisions on the basis of that price and according to their own interests. Usually, the competitive fringe is defined to include all non-OPEC countries. However, under some scenarios it could include certain OPEC members such as Algeria, Iraq, Nigeria and Indonesia. Alternatively, countries currently considered to be in the fringe--such as Malaysia, Norway, Egypt and Mexico--could tacitly join the cartel by agreeing to meet some sort of production quota.

Our treatment of the cartel's decision-making process therefore accounts for the wide array of potential production decisions that might be taken by the cartel under various scenarios, ranging from complete dissolution of the cartel to the participation within the cartel of various members of the competitive fringe.

3.3.1 Model Structure

The CERI world oil supply model consists of four major components:

(i) Drilling Activity Submodel, which projects combined exploratory and development drilling by region as a function of price and the cost of capital;

(ii) Reserves Additions Submodel, which projects reserves additions by region as a function of cumulative drilling effort;

(iii) Production Submodel, which projects productive capacity and actual oil production by region as the combined result of the development of newly found reserves and existing capacity; and

(iv) Cost Submodel, which calculates marginal supply costs and the distribution of operating costs across existing fields by region.

The regional aggregation employed in the world oil market supply model is described in the country-by-country assessment of future crude oil supplies contained in Section 3.5.1.1.

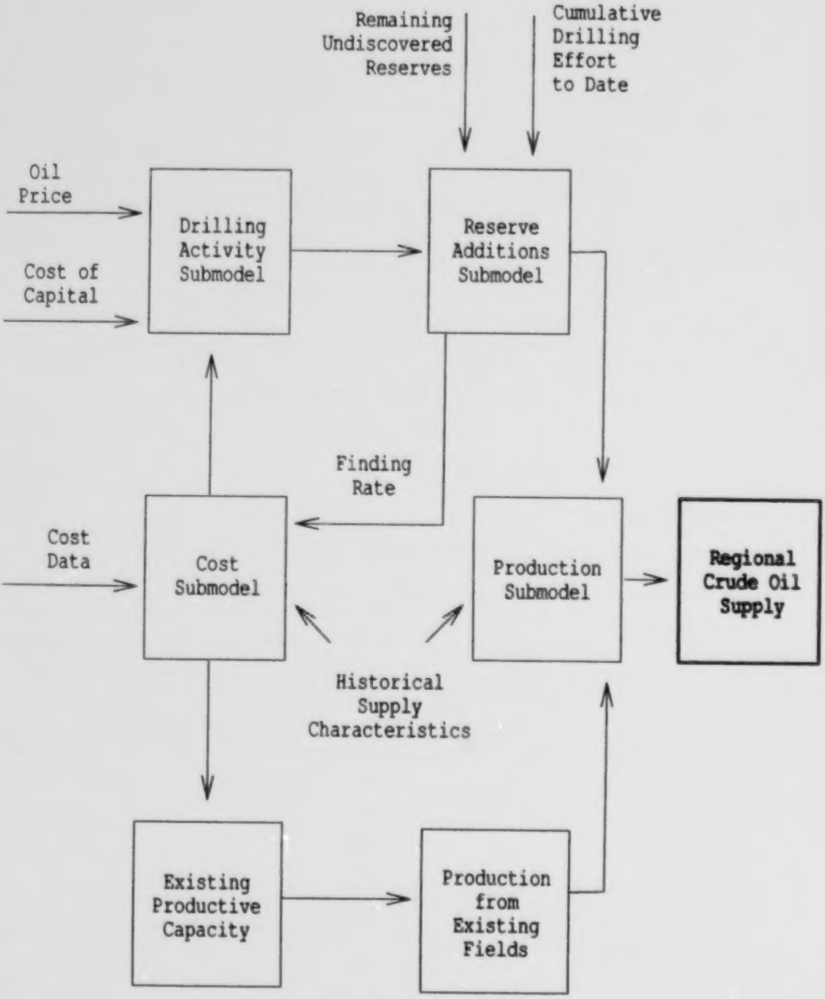
As illustrated in the simple schematic view of the analytical framework provided in Figure 3.6, the driving force behind each region's time path of oil production is the level of drilling activity. The projected level of drilling activity determines the pace of future reserves additions. Production from new reserves additions is estimated from the region's historical supply characteristics and added to production from existing fields to project its total productive capacity. The cost submodel takes the world oil price and determines what volume of this productive capacity should be shut-in at that price, to project actual crude oil production. It also calculates the marginal cost of incremental oil supplies, which is fed into the drilling submodel to provide some indication of the profitability of exploration and development activity in that region. A brief discussion of each of the four submodels is provided below.

3.3.1.1 The Drilling Activity Submodel

There have been numerous varieties of economic models developed to forecast levels of drilling activity. Most of these models have focussed on forecasting either drilling footage, number of wells drilled, or exploration and development expenditures, in very mature supply regions like the U.S. or Canada.[5] Typically, an econometric type of approach has been used in which one of these measures of drilling activity is estimated as a function of a number of variables, including:

(i) expected profitability, which is usually represented by a producer netback calculated as the oil price net of taxes, royalties, and operating and capital costs;

Figure 3.6
Schematic View of the
World Oil Supply Model


Remaining
Undiscovered
Reserves
Cumulative
Drilling
Effort
to Date
Oil
Price
Cost of
Capital
Drilling
Activity
Submodel
Reserve
Additions
Submodel
Finding
Rate
Cost
Data
Cost
Submodel
Production
Submodel
Regional
Crude Oil
Supply
Historical
Supply
Characteristics
Existing
Productive
Capacity
Production
from
Existing
Fields

Source: Canadian Energy Research Institute.

(ii) expected returns to drilling, usually measured by past drilling success rates, reserves discovered per well, or successful drilling footage;

(iii) resource depletion, which attempts to account for the impact of declining finding rates and poorer quality reserves on future supply costs and hence on profitability; and

(iv) cost of capital, which serves to represent the opportunity cost of drilling activity and the actual cost of debt.

However, as noted above, most studies have focussed on mature supply regions where data on drilling activity, costs, fiscal systems and financial variables are widely available and fairly reliable. In attempting to apply this type of methodology to regions around the world, we were forced to deal with the realities of limited and poor quality data. To make this type of approach analytically tractable a number of simplifying assumptions were necessary. First, drilling equations were estimated for total drilling activity measured in drilling footage. No distinction was made between exploratory and development drilling or between gas-directed and oil-directed drilling activity. Historical data on annual drilling footage by region was obtained from the World Oil magazine.

Second, drilling equations were estimated as a function of the following variables:

(i) A representative measure of world crude oil price to proxy the expected profitability of oil production. The coefficient on this variable captures the impact of changes in oil prices on drilling levels. Clearly the preferred measure is, as mentioned above, a producer netback. However, we were restricted to using a world price series because a comprehensive compilation of fiscal and cost data across all producing countries was considerably beyond the scope of this study. The price variable is constructed by obtaining a price series for a representative crude type (Saudi Arabia light-34, obtained from Petroleum Intelligence Weekly; official crude prices until 1978, spot prices thereafter) and deflating it by the U.S. consumer price index.

(ii) The U.S. long-term corporate bond rate to proxy the opportunity cost of drilling activity and the cost of debt. If efficient capital markets are assumed, then this series should provide an adequate approximation of the cost of capital.

(iii) The reserves life index to proxy the utilization rate of reserves. A high reserves to production ratio is

> indicative of ample reserves of existing production levels, and signals a less urgent need for drilling activity. Conversely, a low reserves to production ratio signifies potential future supply shortages and creates an incentive to drill.

In many instances the fit of these equations is relatively poor, stemming primarily from the lack of country-specific information required to construct a profitability time series. It is also the case that this particular approach is more conducive to analysis of decision-making within private companies, as opposed to crown or national corporations. As such, the methodology may not accurately represent the drilling decision process in many OPEC and Third World countries. It is important to stress, however, that the primary objective of the drilling model is to project average drilling activity over time by region. By incorporating the world oil price into the model, it is possible to capture the impact of changing prices on the average level of drilling activity.

3.3.1.2 The Reserves Additions Submodel

A number of different methodologies have been developed to project the amount of petroleum resources that might be discovered in a particular region.[6] The approach we have chosen is loosely classified as "rate of effort" and is closely related to the pioneering work of M. King Hubbert.[7] Hubbert developed the "life cycle" concept of a fossil fuel to generate not only an estimate of what ultimately will be discovered in a region, but also the time path of rates of discovery and production. "Rate of effort" models differ in that they generate estimates of rates of discovery and production as a function of cumulative exploratory effort rather than time. This provides a very convenient link between the drilling and reserves additions submodels and allows us to project reserves additions as a function of price.

The "rate of effort" approach requires the fitting of a cumulative growth curve to historical data on cumulative discoveries and drilling activity. The slope of the growth curve represents the rate of discovery, more commonly known as the finding rate and defined in this case to be the reserves added in any year divided by total feet drilled in that year.

Historical data on finding rates show wide fluctuations on a yearly basis. However, some important general trends can be observed. Examination of the data suggests that our representation of the discovery process should reflect the following temporal pattern.

(i) In relatively unexplored regions, finding rates may initially increase over time as knowledge of the regions geology is accumulated and drilling efforts show the product of this increased knowledge;

(ii) At some point in time as the cumulative level of drilling in a region increases, the returns to drilling will begin to diminish. This is supported by the widely accepted hypothesis that the underlying distribution of pool sizes is lognormal.[8] Thus, the larger pools will tend to be discovered early in the exploration process. The trend of discoveries is a declining pool size range which is a function of the lognormal pool size distribution; and

(iii) Eventually, the finding rate will decline to zero as the total amount of reserves discovered approaches the region's ultimate potential.

This estimation procedure requires data on cumulative feet drilled, cumulative discoveries, and ultimately recoverable crude oil resources by region. Data from the World Oil magazine is used to construct time series for the first two variables. Estimates of the likely undiscovered recoverable oil resources at three different probability levels were obtained from a number of sources to generate estimates of ultimate resource potential.[9] The high degree of uncertainty associated with these estimates is addressed by fitting cumulative growth curves using the ranges provided in these studies (see Appendix D for an illustration of this approach, using Egypt as a case study).

Once the parameters describing the cumulative reserves growth curves have been determined for each supply region, they are used to project future finding rates as a function of forecast drilling activity. The estimated finding rates in any year are then multiplied by that year's forecasted drilling activity to yield an estimate of expected reserves additions.

3.3.1.3 The Production Submodel

In all oil fields, the rate of production eventually enters into a period of decline, due to pressure loss in the producing formation (this rate of decline can be mitigated by the use of enhanced oil recovery techniques). In the initial years of production, however, a period of flat or even increasing production is usually possible. This varies considerably by field as does the subsequent rate of decline, depending on the regulatory environment, the operator's production strategy, the geological characteristics of the producing formation, and the drive mechanism.

The crude oil productive capacity in any region is determined as the sum of production from existing fields and new production brought on stream through reserves additions. In the former case, the rate of decline in any region is approximated on an aggregate basis using the widely held assumption that decline rate is equal to the ratio of annual production to reserves, as would be true under conditions of exponential decline. For new production from reserves additions, a degree of flexibility was introduced by allowing the user to specify production profiles for future reserves additions in any region, based on specialized knowledge that might be available about the producing characteristics of that region. This feature is an attempt to deal with the following uncertainties:

(i) the pace of development for future reserves additions. For example, in a developing country one might not see a new discovery reach peak production for a number of years because of infrastructure requirements or other constraints. Conversely, in Canada and the U.S., new discoveries are generally in production that same year and reach peak production very rapidly; and

(ii) the rate of decline which, as noted above, differs considerably by region and field. In the U.S., for example, production generally declines quite rapidly in the early years of a producing well's life before stabilizing at a much lower rate. In the more prolific fields found in the Middle East, very high production rates can be sustained for prolonger periods of time without significant decline.

A critical component of the world crude oil supply/demand balance is the level of natural gas liquids (NGLs) production. If one looks at total world crude oil production compared with demand, a supply shortfall of about 4.5 MMb/d is revealed. This shortfall is largely due to the inclusion of NGLs in the petroleum product consumption statistics. Since the balancing of supply and demand play a critical role in determining prices in our integrated world oil model, the production of NGLs must be accounted for.

As it is beyond the scope of this study to determine NGL production endogenously, we take recourse by specifying the level exogenously. Initial NGL production levels by region are taken from available statistical information and assumed to either grow or decline according to an exogenously specified annual rate. Refinery gain, which is an increase in volume obtained when processing crude oil into lighter products, also contributes to the observed statistical imbalance. Finally, we are also faced with the necessity of assuming future levels of crude oil production in the CPE's, primarily because of the futility of trying to forecast the planning process in these nations. The values assumed for these parameters are presented in Section 3.5.

3.3.1.4 The Cost Submodel

The current instability in the world oil market and the dramatic fall in oil prices during 1986 have stimulated great interest in the lower limit for world oil prices (often referred to as the "competitive floor") and its sustainability over time. Presumably such a situation might develop if OPEC cooperation were to disintegrate and individual member nations began producing at capacity. Alternatively, prices could fall dramatically, but not quite to the competitive floor, if one or more OPEC nations were to completely disregard their production quotas, not an implausible scenario given the cash flow needs of a number of member countries.

The cost submodel of the world oil supply model provides the analytical framework with the ability to consistently analyze this problem through two features:

(i) an algorithm to estimate the distribution of operating costs across existing fields worldwide; and

(ii) an algorithm to estimate marginal supply costs in each supply region.

With information on operating costs it is possible to project where, and by how much, oil production might be shut-in at different price levels.

Our findings suggest that operating costs are generally below $5 per barrel for most oil production today. Therefore, the major impact of lower oil prices will likely be the curtailment of exploratory and development activity around the world. This impact is captured through a decline in drilling activity (and hence a decline in production from newly added reserves). However, by comparing marginal supply costs with price, the relative profitability of continued exploration and development activity in various regions can be assessed. Although drilling activity will not be eliminated in those countries in which cost exceeds price, what little activity that does occur will be directed to those prospects that are economic at very low prices.

Operating Costs

Without making some major simplifying assumptions, the estimation of operating and supply costs by country is a nearly impossible task. The approach taken to estimate average annual field operating costs is, therefore, to assume that they are some fixed proportion of installed field capital. Installed field capital, defined as the cost of development drilling and field equipment, was estimated for over 2000 fields worldwide. This was accomplished for onshore fields by assuming that:

(i) drilling and completion costs are a function of average well depth and geographical location; and

(ii) production, treatment and pumping equipment are a function of field parameters such as average well depth, average flowrate and geographical location.

Cost equations were estimated for drilling costs using U.S. cost data. Estimates of the typical cost of installing field equipment for a representative single onshore producing well in North America at various flowrates were prepared by an outside consultant. These costs were then multiplied by regional factors to account for differences in relative costs around the world.

A similar approach was applied to estimate drilling and equipment costs for offshore fields. Detailed and reliable data on North Sea development and equipment costs is available in a report compiled by Wood, Mackenzie and Co.[10] Four cost categories were identified--drilling and completion costs, platform costs, installation costs, and process equipment costs. While acknowledging that development and operating costs depend heavily on water depth and distance to shore (among other factors), cost equations were estimated only as a function of field capacity and geographical location owing to the lack of additional data. As above, each of these cost categories was multiplied by regional factors to account for differences in cost world wide.

To implement the cost equations, field specific information is required on:

(i) total field production and whether the field is onshore or offshore;

(ii) the number of producing wells and the percentage of those under artificial lift or natural pressure drive;

(iii) the average depth of producing wells; and

(iv) average specific gravity of oil found in the field.

This data is available for a significant portion of the world's producing fields through Oil and Gas Journal's International Petroleum Encyclopedia. A detailed data base for the 1000 largest producing fields in the U.S. was obtained to supplement this data.

Average annual operating costs for each of the fields contained in the data base are calculated by assuming they are a fixed proportion (15 percent) of installed field capital as estimated using the cost equations. A per barrel estimate of average field operating costs is then calculated as the yearly operating costs divided by annual field production. With this information, operating cost curves are constructed for each supply region having sufficient data. These operating cost curves describe the distribution of operating costs across each region's existing oil production as a function of price. Given the world oil price, the amount of oil production that might be shut-in in any region can be estimated as the intersection of the world oil price with the operating cost curve.

Figure 3.7 presents an aggregate representation of the operating cost curves developed for the various regions. Of the 32 MMb/d in crude oil production accounted for in the data base, over 94 percent is estimated to be lifted at costs of less than $6.00 per barrel (1985 U.S. dollars). These results reflect a general concensus among world oil market analysts that most production around the world is lifted at costs around or below $5 per barrel. It should be recognized that actual data on operating costs is extremely difficult to obtain for a number of reasons, including corporate confidentiality. Where documented costs are available, they have been incorporated into the model.[11]

Marginal Supply Costs

The various components of the world oil supply model, when combined with the cost submodel, provide a consistent basis for estimating marginal supply costs in each supply region. The simplifying assumptions and steps required to make these calculations are:

(i) a representative field size in each region is calculated as the weighted average of existing field sizes;

(ii) the representative field is assumed to be produced at the region's historical decline rate;

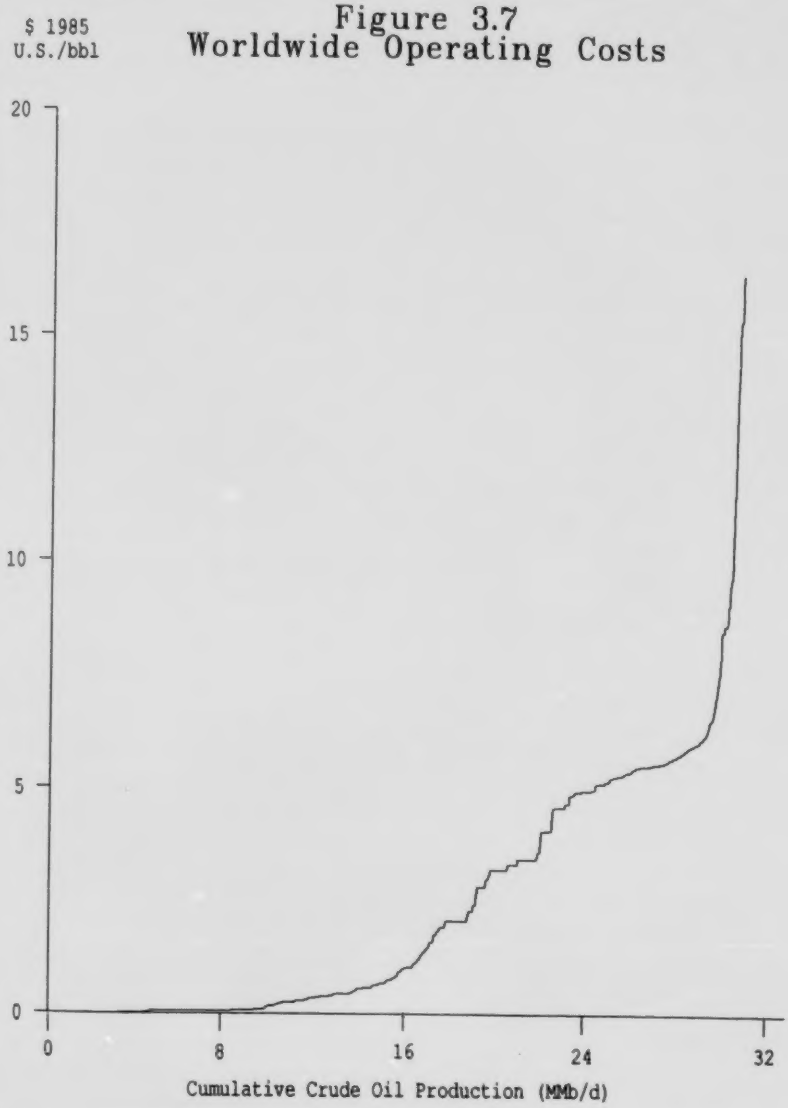
(iii) the number of producing wells is calculated as the total field production (calculated from the assumed decline rate) divided by the region's weighted average flow rate per well;

(iv) the depth of these wells is calculated as the weighted average of existing well depths; and

(v) the total amount of drilling required to find and develop the representative field is calculated as the field size divided by the regional finding rate.

This is sufficient information to estimate the capital cost of finding and developing a representative field as well as the average per barrel operating costs. The marginal supply cost is calculated as the price required to just make the field economic, by multiplying the required capital

Figure 3.7
Worldwide Operating Costs



SOURCE: Canadian Energy Research Institute.

investment per daily barrel by the sum of the minimum acceptable rate of return and the historical decline rate, and adding operating costs.[12] The minimum acceptable rate of return assumed in these calculations was 16 percent, allowing 8 percent for the financial opportunity cost and 8 percent for the risk premium on diversified oil operations.[13] Table 3.6 in Section 3.5 presents regional marginal supply costs estimated as of 1987.

3.4 Illustrative Supply Model Results

The supply side of the world oil market model can be run independently by specifying world oil prices, interest rates and the underlying estimates of ultimate potential to be used in the finding rate calculations. This section presents the results of a series of such runs to illustrate the sensitivity of the results to changes in price and the level of undiscovered crude oil resources.

Since OPEC is the residual supplier in the world oil market, it is the competitive fringe that is of crucial importance to the analysis in terms of the sensitivity of supply to changes in price, and of uncertainty regarding long-term production potential. OPEC's hopes for increasing their market share in the future rest on a recovery in crude oil demand growth that is not fully offset by increases in non-OPEC production. Therefore, in each of the cases presented below, we focus exclusively on the supply projections for non-OPEC countries.

The first case (which we term the test case) looks at a plausible scenario in which prices rise to $27 per barrel by the year 2000 (this is the same price path used for the test case examined in Chapter 2). Next we assess the impact of sustained low prices under two scenarios. In the first sensitivity case, prices are assumed to remain constant at $17.50 per barrel throughout the forecast horizon. In the second, prices remain constant at $17.50 until 1990 whereupon they fall to $7.50 per barrel for the next 5 years before returning to $17.50 for the remaining years of the forecast horizon. The final set of sensitivities examine world oil supplies under three different resource scenarios, assuming a flat $17.50 per barrel oil price until 2000 to abstract from price effects. Detailed country-specific results are discussed only for the plausible reference case. Here we also present some salient historical statistics and discuss some expected short-term developments.

3.4.1 Test Case

Table 3.3 presents the price track assumed for this case. Oil prices are assumed to rise quite slowly for the first 7 years, reaching $21.17 per barrel by 1993. The rate of increase accelerates over the latter years, with

TABLE 3.3

REFERENCE CASE OIL PRICE ASSUMPTION

Year	Price ($1987 U.S./bbl)
1987	18.70
1988	17.50
1989	18.75
1990	19.45
1991	19.95
1992	20.50
1993	21.20
1994	21.90
1995	22.75
1996	23.66
1997	24.40
1998	25.20
1999	26.20
2000	27.00

SOURCE: Canadian Energy Research Institute.

TABLE 3.4

ASSUMED NGL PRODUCTION LEVELS AND NET CPE EXPORTS (Mb/d)

Year	OPEC NGL Production	Non-OPEC NGL Production	Net CPE Exports
1987	1,409	2,811	2,240
1988	1,444	2,798	2,170
1989	1,479	2,786	2,200
1990	1,516	2,775	2,220
1991	1,554	2,765	2,120
1992	1,594	2,755	1,810
1993	1,634	2,747	1,500
1994	1,675	2,740	1,300
1995	1,718	2,734	1,100
1996	1,762	2,728	900
1997	1,808	2,724	700
1998	1,855	2,720	500
1999	1,903	2,718	250
2000	1,953	2,716	0

SOURCE: Canadian Energy Research Institute.

prices reaching $27 per barrel by the year 2000. Interest rates are assumed to remain constant at 9 percent throughout the forecast horizon.

Under this price scenario, total non-OPEC crude oil production, which is estimated to be 22.8 MMb/d in 1987, is projected to expand slowly at about 250 Mb/d per year over the next 4 years (see Figure 3.8). Production peaks at 23.6 MMb/d in 1992 before declining thereafter. From 1993 to 1995, the rate of decline is fairly gradual. Total production falls at an average annual rate of about 0.7 percent to 23.1 MMb/d by 1995. Thereafter, the rate of decline accelerates, averaging 1.6 percent for the remaining years. At the end of the century, total non-OPEC, non-CPE crude oil production is projected to stand at 21.5 MMb/d, 1.5 MMb/d lower than 1987 production.

Crude oil production in the OECD countries is expected to decline significantly over the forecast horizon, from 16.7 MMb/d in 1987 to 13.9 MMb/d by the year 2000. This decrease is partially offset by a sizable expansion in the productive capacity of the LDC countries. Crude oil production in these countries is projected to increase from about 8.9 MMb/d to 10.2 MMb/d over the same period.

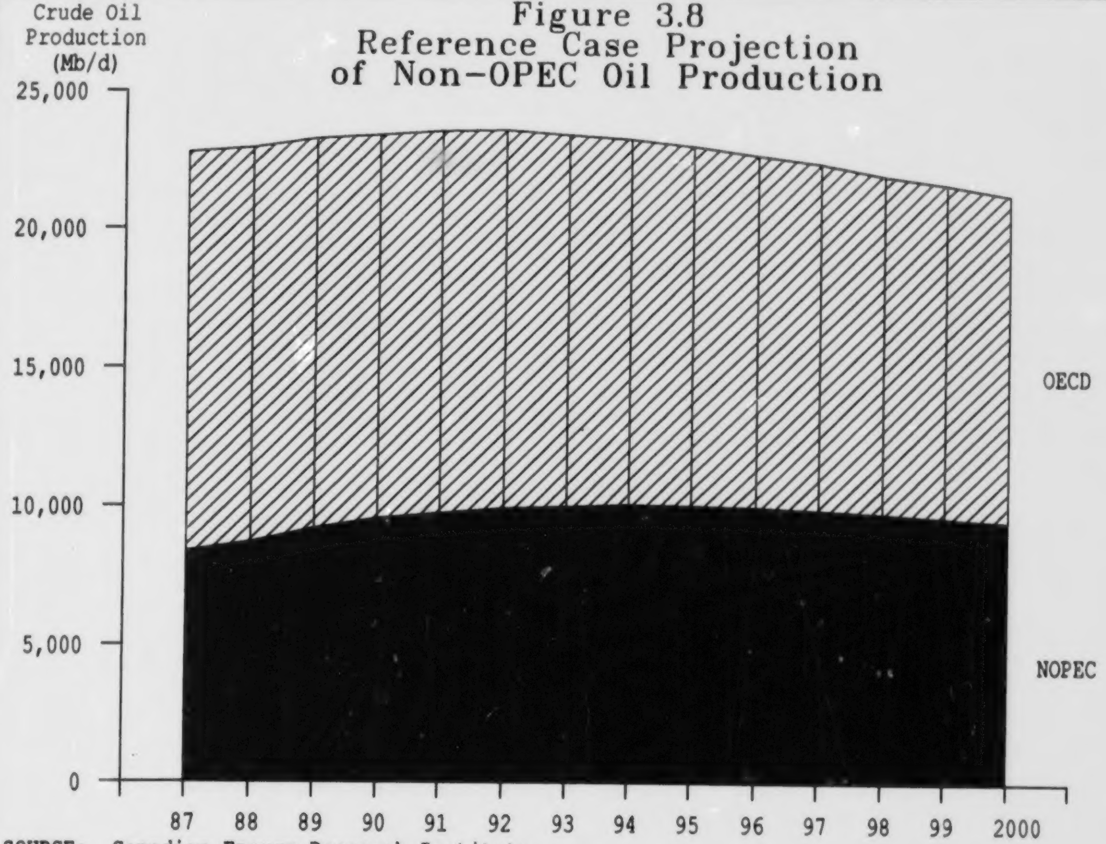
As discussed in Section 3.4, assumptions regarding the level of world NGL production and net CPE exports are required to generate a consistent forecast of world oil supplies that equates to world demand. Table 3.4 presents the assumed values of these parameters. OPEC's production of NGLs is assumed to increase gradually throughout the forecast horizon, from 1409 to 1953 Mb/d. Total non-OPEC NGL production is assumed to decline slightly, from 2811 to 2716 Mb/d between 1887 and 2000. The basis for these assumptions is taken from the U.S. Energy Information Administration's (EIA) International Energy Outlook: 1986.

A review of the literature suggests that a plausible range for net CPE exports in the year 2000 is -1.0 to 1.5 MMb/d. Our reference case is middle of the road, assuming that CPE net exports will fall and gradually disappear by the year 2000. The potential impact of this assumption is explored further in Chapter 4. Refinery gain was assumed to average 1.1 MMb/d per year through the forecast horizon.[14]

3.4.1.1 Country-by-Country Assessment of Future Crude Oil Supplies

Aggregate statistics such as those presented above mask some interesting and important regional trends. Table 3.5 presents a detailed regional breakdown of the supply projections shown in Figure 3.8. A comparison of full cycle supply costs, as estimated by the cost component of the supply model, and representative production characteristics for these

Figure 3.8
Reference Case Projection of Non-OPEC Oil Production



SOURCE: Canadian Energy Research Institute.

TABLE 3.5

HISTORICAL AND PROJECTED LEVELS OF NON-OPEC CRUDE OIL PRODUCTION BY REGION

(Mb/d)

	1970	1980	1986	1987	1990	1995	2000
Angola	103	271	604	650	675	673	612
Argentina	393	491	430	414	397	402	402
Australia	180	408	542	552	526	486	443
Brazil	156	182	593	608	714	749	653
Canada	1,200	1,424	1,472	1,493	1,341	1,276	1,304
Colombia	267	183	353	426	524	572	514
Egypt	416	698	930	997	1,153	454	689
India	100	230	674	756	828	703	535
Malaysia	160	504	709	685	745	855	868
Mexico	429	1,936	2,500	2,585	2,827	3,228	3,548
North Sea	2	2,134	3,325	3,420	3,593	3,347	2,593
Other Middle East	343	512	873	875	1,304	1,531	1,279
United States	9,637	8,596	8,867	8,481	7,880	7,283	7,001
Western Europe	382	285	406	494	553	583	496
Other	211	407	355	372	388	415	424
Total	13,819	18,261	22,633	22,808	23,448	22,606	21,361

SOURCE: World Oil, Various Issues; Canadian Energy Research Institute.

countries is contained in Table 3.6. Estimates of the remaining undiscovered resources in these countries at various probability levels are shown in Table 3.7. It should be noted that the modal estimates of the remaining resource base were used to calculate finding rates in the reference case scenario.

Following is a brief discussion of the key characteristics and scenario results for each of the countries specified in the supply side of the World Oil Market model, under the test case scenarios.[15]

Angola (Cameroon, Congo): Crude oil production in these countries has increased sixfold since 1970. Projected finding rates in 1987 for the region stand at about 329 barrels per foot drilled (b/ft), and the weighted average flowrate per producing well at about 1010 b/d. Full cycle replacement costs are estimated to be $9.90 per barrel, well below today's price level. Angola's current output of 300 Mb/d is likely to increase by up to 80 percent by 1990 as the result of recent discoveries in the Cabinda enclave. In the Congo, a new offshore discovery will help maintain total domestic output at 120 Mb/d; further offshore discoveries linked to the Cabinda structures in neighbouring Angola could allow for expanded exports. Our long-term projections indicate that production in this region will peak at about 682 Mb/d in 1992, after which it will slowly decline to 612 Mb/d as the returns to drilling diminish and production from new reserves additions is no longer able to offset production declines.

Argentina: Argentina stands in contrast to most of the NOPEC countries in that its crude oil resource base is relatively mature and has been extensively explored. As a result, finding rates are the lowest of any NOPEC country at 29 b/ft and full-cycle replacement costs rank third behind Peru and Brazil at $11.60 per barrel. No significant discoveries have been made recently but, if the high level of drilling activity of past years is maintained in the future, production should remain relatively stable, declining from 414 to 402 Mb/d between 1987 and 2000.

Brazil: Although Brazil's finding rates are over three times as high as Argentina's, full-cycle replacement costs are estimated to be slightly higher due to the large percentage of offshore production (50 percent) and the depth of water in which most of these reserves are found. Sizable reserves have recently been proved up in the super deepwater Albacora, Marlin and Campos basins and promising discoveries have been made in the Western Amazon region. Although financial requirements will delay full scale development of these reserves, they will contribute significantly through the 1990's. Our projections indicate that Brazil is not likely to meet its stated 1989 production target of 740 Mb/d until 1991. Production is estimated to

TABLE 3.6

CRUDE OIL REPLACEMENT COSTS IN THE NON-OPEC COUNTRIES

	Percentage of Production Onshore	Projected Finding Rates as of 1987 (b/ft)	Weighted Average Flow Per Well (b/d)	Weighted Average Producing Well Depth (feet)	Replacement Costs as of 1987 ($1985 U.S.)
Angola	31	329	1,010	5,237	9.98
Argentina	100	29	77	8,039	11.60
Australia	12	97	4,646	7,330	21.46
Brazil	28	128	2,435	3,869	12.98
Canada	100	14	96	5,189	11.80
Colombia	100	103	968	8,347	4.83
Egypt	25	405	3,148	6,156	9.09
India	100	126	338	4,810	9.20
Malaysia	41	280	1,132	5,424	8.31
Mexico	34	1,184	11,600	12,051	4.66
North Sea	0	365	7,217	8,503	11.67
Other Middle East	95	370	1,459	5,799	2.50
United States	82	10	131	10,390	13.50
Western Europe	53	32	4,413	5,654	9.92

SOURCE: Canadian Energy Research Institute.

TABLE 3.7

ULTIMATELY RECOVERABLE CONVENTIONAL CRUDE OIL RESOURCES IN THE NON-OPEC COUNTRIES
(billions of barrels)

	Cumulative Production (as of 1986)	Proven Reserves (as of 1986)	Reserves to Production Ratio (as of 1986)	Undiscovered Recoverable Resources		
				(95%)	(Mode)	(5%)
Angola	2.0	3.3	14.9	4.6	20.8	44.6
Argentina	4.6	2.2	12.9	1.3	2.6	6.7
Australia	2.6	1.9	9.5	3.0	5.0	10.0
Brazil	2.1	2.4	12.1	1.1	2.0	7.5
Canada						
Western Canada	12.7	4.8	8.9	2.9	3.6	4.8
Frontier	0	2.6[a]	0	7.3	26.0	52.7
Colombia	3.2	2.0	15.3	0.7	1.7	4.9
Egypt	4.9	6.2	18.4	0.4	3.2	7.4
India	2.3	5.2	21.2	1.0	3.0	7.0
Malaysia	3.5	4.8	18.6	2.3	11.3	16.5
Mexico	13.7	54.9	60.1	14.9	48.4	138.4
North Sea	9.1	16.4	13.5	8.1	15.4	27.4
Other Middle East	7.6	6.9	21.7	3.8	7.3	13.5
United States	143.0	27.3	8.4	42.0	60.3	82.8
Western Europe	6.4	2.9	15.8	0.6	1.3	8.3
Total	218.0	141.2		91.7	185.9	379.8

SOURCE: World Oil, Various Issues; Canadian Petroleum Association, Statistical Handbook (1986); Geological Survey of Canada, Conventional Oil Resources of Western Canada (1987); Geological Survey Circular 860, "Estimates of Undiscovered Recoverable Conventional Resources of Oil & Gas in the United States" (1981); United States Department of Energy, Energy Information Administration, "Foreign Energy Supply Assessment Series"; and Masters, Root and Dietzman, Distribution and Quantitative Assessment of World Crude Oil Reserves.

[a] Referred to as discovered resources.

peak in 1993 at 758 Mb/d before declining to 653 Mb/d in 2000, some 45 Mb/d greater than the crude oil output level achieved in 1987.

Canada: Canadian production is projected to fall by 205 Mb/d over the forecast horizon. However, this is largely the result of increased production from Canada's sizable frontier resources. Under the prices assumed in this case, production from the Western Sedimentary Basin steadily decreases, reflecting the state of depletion in this supply basin. Finding rates are 20 percent higher, and supply costs 20 percent lower, than those seen in the U.S. After 1992, higher prices allow for staged development of frontier reserves, partially offsetting the fairly rapid decline in Western Sedimentary Basin production so that by 2000, total Canadian crude oil production stands at about 1.3 MMb/d.[16]

Colombia (Bolivia and Chile): Colombia is at the center of current optimism regarding potential crude oil development in South America. Increased exploration activity of some 30 percent in 1986 added in excess of 100 million barrels of proven reserves, causing some analysts to speculate that production could grow almost 50 Mb/d per year over the next 5 years as the gigantic Cano Limon field is more fully developed. Pipeline development valued at $2.2 billion is to be undertaken to connect recent discoveries in the central and eastern Llanos regions to the existing transportation network. Full-cycle replacement costs are very attractive, standing at about $5 per barrel in 1987, due to relatively high finding rates and prolific flow rates per producing well. Our supply projection suggests that production will not grow by more than 25 Mb/d per year over the next 5 years. Production is estimated to peak at 573 Mb/d in 1994, falling to 514 Mb/d by the year 2000 as the region's resource base is gradually depleted.

Egypt (Tunisia): Production in these two countries has more than doubled since 1970. High projected finding rates and high average flowrates per well combine to yield full-cycle replacement costs for the region of under $10 per barrel. Over the short term, a joint venture between Egypt's national oil company and several western firms, which resulted in three large discoveries in the Western desert during 1987, will permit production to edge past the 1 MMb/d mark by 1990. Reaching this production target would require that Egypt abandon its tacit support of OPEC, delivered in the form of voluntary output controls. Our projections suggest that combined production in the two regions will peak at about 1153 MMb/d in 1990. As Egypt is thought to have a relatively small resource base--with only about 3.2 billion barrels remaining to be discovered--projected finding rates fall quite rapidly so that production could be as low as 690 Mb/d by the year 2000.

India (Pakistan and Burma): Crude oil output in these countries has expanded 675 percent since 1970. India is maintaining a vigorous exploration program aimed at achieving self-sufficiency. Production targets have been set that would see output increase from 610 Mb/d in 1986 to 720 Mb/d by 1990, and 800 Mb/d by 1995. Our projections for the region, however, suggest that although production can be increased in the short term--from 756 Mb/d in 1987 to 828 Mb/d in 1990--rapidly diminishing returns to drilling activity will result in production falling to 535 Mb/d by the year 2000.

Malaysia (Brunei, Vietnam, Thailand): This region has more than quadrupled its crude oil output since 1970. The regions resource potential is fairly significant, with over 11 billion barrels likely remaining to be discovered. Projected finding rates in 1987 stand at about 280 b/ft and full-cycle replacement cost at about $8.31 per barrel, suggesting considerable potential for increased production down the road. Malaysia reduced production by 5 percent to 475 Mb/d in 1987 as part of an agreement to support OPEC's price and quota plan. The country has set a production target of 540 Mb/d for 1988, and new production sharing contracts being negotiated with oil companies should help maintain growth in output. Our projections indicate that the region's output will grow significantly over the forecast horizon. Finding rates are not projected to decline substantially over the next 14 years. Combined with projected drilling activity levels, this suggests that production could grow from 685 Mb/d in 1987 to just over 860 Mb/d by the year 2000.

Mexico: Mexico is expected to contribute the largest increment to future production, with over 1 MMb/d to be added by the year 2000. This is indicative of the country's massive untapped reserves--the reserves to production ratio in 1986 exceeded 60 years and over 48 billion barrels likely remain to be discovered--and represents a fairly modest estimate of the country's potential productive capacity in 2000. If drilling efforts are intensified above projected levels, it is conceivable that Mexican production could double over the next 10 to 15 years. Finding rates exceed 1000 b/ft and full-cycle replacement costs are estimated to be the second lowest of the NOPEC countries, at $4.66 per barrel.

North Sea: In the U.K sector of the North Sea, production has peaked in some 27 of 33 producing fields (including the Brent field), and total output has started a gradual downward slide, slipping by about 100,000 b/d to less than 2.5 MMb/d last year. However, 1987 was the most successful year for new discoveries in a decade, with 25 significant finds totaling some 900 million barrels of proven liquid reserves--a reserves to replacement ratio of over 90 percent. New production from the North Brae play and the onshore

Wytch Farm field will largely offset the decline from other fields in coming years, so that overall production will decline much more slowly than had previously been expected. Dramatic reductions in oil field service costs have allowed new exploration to continue despite lower oil prices; for example, the price of semi-submersible and jack-up drilling rigs was averaging $16,000 ($U.S.) per day late last year, versus $100,000 or more per day in the early 1980s.[17] In the Norwegian sector of the North Sea, very healthy growth in output is expected, likely sufficient to offset the effect on total non-OPEC supply of any near term declines in U.S. production. Technical production potential far exceeds projections of actual future production, reflecting the government's enforcement of a slow schedule for new development--both to provide tacit support to OPEC and to reduce the inflationary effects of a sudden burst of investment expenditure. Production is expected to increase by at least 100 Mb/d in 1988, to about 1.1 MMb/d, with a potential level of 1.6 MMb/d attainable by 1992 on the basis of eight currently approved development projects. Estimated full cycle costs below $12 per barrel in 1987 suggest that this type of growth will be justified for some time to come. Our longer-term projection for the North Sea suggests that production will peak in 1992 at about 3.7 MMb/d, up from 3.4 MMb/d in 1987. Total production in the North Sea region is expected to grow slightly over the next 10 years, due primarily to a healthy expansion in Norway's output. However, this growth will not be sufficient to offset an eventual decline in the U.K sector. Total North Sea production is projected to fall to 2.6 MMb/d by the end of the century.

Other Middle East (Oman, Syria, North and South Yemen, Bahrain): Although the resources in these countries pale by comparison with the Gulf members of OPEC, high finding rates and very prolific producing wells combine to give the region the lowest full-cycle replacement costs of the NOPEC countries, at $2.50 per barrel. Although North and South Yemen are not significant oil producers at the current time, both are likely to be important sources of incremental supplies in the near term. North Yemen entered the world oil market in December 1987 with initial exports of some 150 Mb/d via a 270-mile pipeline through the Red Sea port of Salif. The pipeline is capable of handling up to 450 Mb/d, a volume that could be easily supplied from the country's proven reserves of more than 1 billion barrels. The South Yemen government claims reserves even greater than those of North Yemen. Although production is currently limited to 10 Mb/d, development of required infrastructure should allow for production in excess of 200 Mb/d by the mid-1990s. Oman, a producer that has been voluntarily restraining production to support OPEC, also has the resource base to expand production considerably beyond 1987 production levels of 600 Mb/d by the mid 1990s. Syria's crude oil output, which grew by 25 percent in

1986, is expected to see similar increments added in the future due to new discoveries. In total, Other Middle East production is projected to grow almost 73 percent, from 875 Mb/d to 1531 Mb/d between 1987 and 1995. After this point, a projected decline in the regions finding rate suggests that long-term prospects for additional discoveries will diminish and production will fall to 1279 Mb/d by the year 2000.

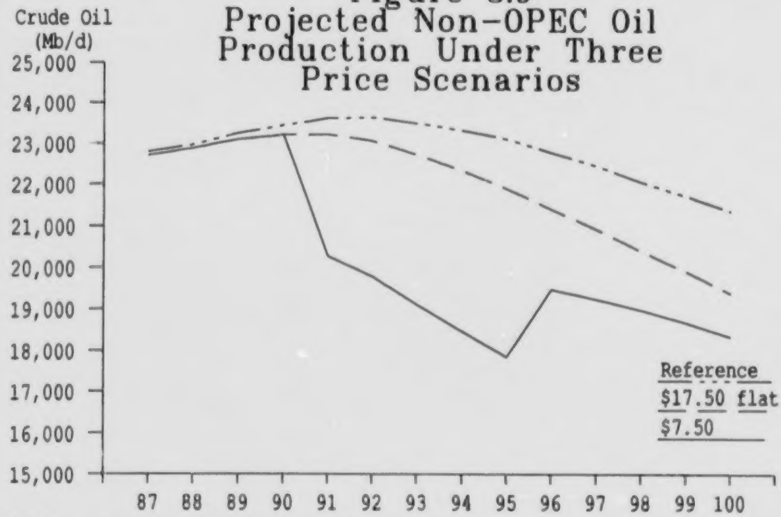
United States: The U.S. is the largest single source of the projected decline in total non-OPEC oil production. Total U.S. crude oil liquids production is estimated to fall by 1.8 MMb/d over the forecast horizon. The extremely low finding rates (10 b/ft in 1987) and high replacement costs (exceeding $13 per barrel) indicate the degree to which the country has been explored and the state of depletion that has been reached. It is highly unlikely that any gigantic fields remain to be discovered in the U.S. (with the possible exception of the high cost offshore or frontier regions). Future attention will have to focus on the finding and development of small pools, on increased levels of infill drilling, and on the vigorous application of enhanced oil recovery techniques.

Western Europe: Over the short term, some expansion in the combined output of the Western European countries is likely. Full development of the Vega heavy oil field offshore Sicily will add 70 Mb/d to Italy's output by 1989, with a smaller increment expected in 1990. Small participation by Denmark and Germany in the North Sea will also allow for modest increments in production. However, most of these countries have been extensively explored and are subject to fairly low finding rates on average--estimated at about 32 b/ft in 1987. Over the longer term, finding rates are expected to diminish fairly slowly, allowing output to remain fairly stable at about 496 Mb/d throughout the forecast period.

3.4.2 Low Oil Price Scenarios

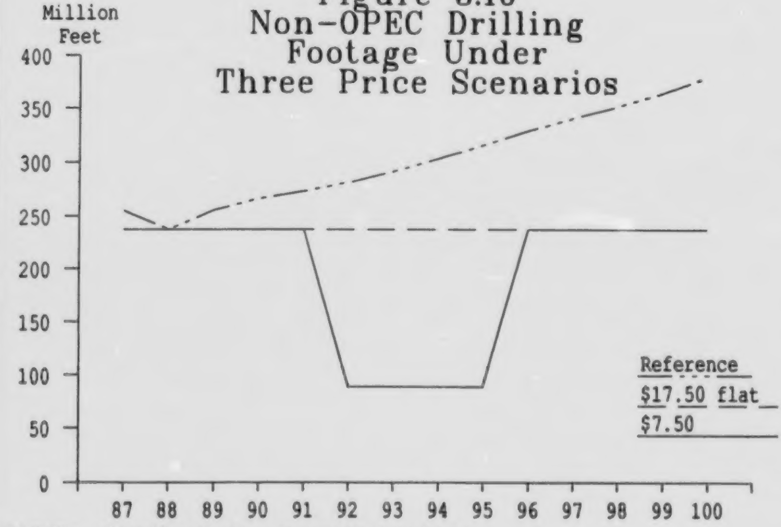
Figure 3.9 compares the projections of non-OPEC oil supplies under three price scenarios--the test case discussed above, a flat $17.50 per barrel oil price case, and a case which assumes prices to be constant at $17.50 to 1990, fall to $7.50 per barrel through 1995, and then to rise to $17.50 per barrel through 2000 (a "price crash" scenario). As illustrated, there is a considerable supply response under these alternative scenarios. Under the flat $17.50 scenario, total non-Opec supplies in the year 2000 are estimated to be about 2 MMb/d less than under the reference case. Production peaks in 1992 at 23.2 MMb/d compared to 23.6 MMb/d in the same year under the reference case. In the scenario where oil prices fall to $7.50 between 1990 and 1995, the $10 drop in prices causes the shut-in of nearly 1.7 MMb/d of production around the world. Non-OPEC production continues to fall rapidly

Figure 3.9
Projected Non-OPEC Oil Production Under Three Price Scenarios



SOURCE: Canadian Energy Research Institute.

Figure 3.10
Non-OPEC Drilling Footage Under Three Price Scenarios



SOURCE: Canadian Energy Research Institute.

through 1995 because of drastically curtailed drilling programs, reaching a low of 17.8 MMb/d. A return to higher prices in 1996 restores some shut-in production and drilling activity so that production rebounds to 19.5 MMb/d. By the year 2000, total non-OPEC production stands at 18.4 MMb/d, compared to 19.4 and 20.4 MMb/d under the flat price and reference case scenarios, respectively.

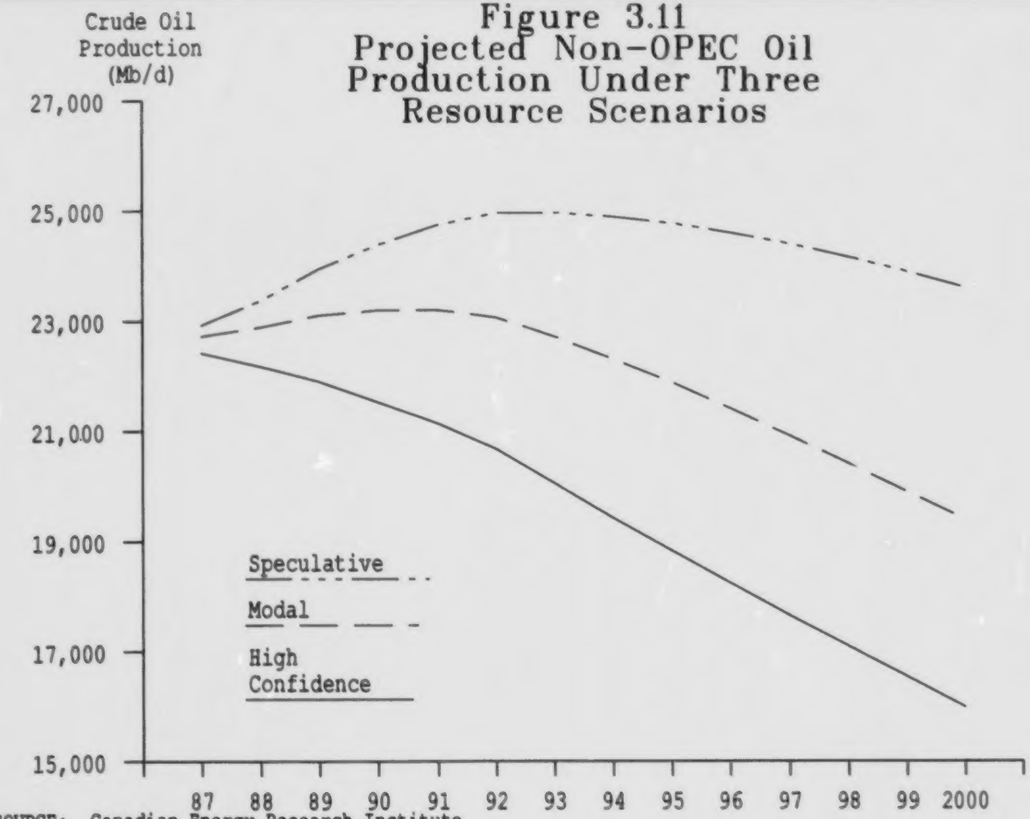
As discussed in Section 3.4, the level of drilling activity ultimately determines the degree to which production from future reserves additions can offset the decline in production from existing fields. Figure 3.10 compares projected levels of non-OPEC drilling footage under each of these scenarios. Under the flat oil price scenario, total non-OPEC drilling footage is projected to be 12 percent less in 1990, 33 percent less in 1995 and 60 percent less in 2000 than the footage drilled under the reference case. Under the price crash scenario, the $10 per barrel drop in oil prices causes annual drilling footage between 1991 and 1995 to plummet to less than one third the level projected under the reference case. Over 90 percent of this reduction in drilling activity is projected to occur in the OECD countries. This reflects the high marginal supply costs and poor returns to drilling in most of these countries. In contrast, footage drilled in the NOPEC countries is projected to fall slightly more than 30 percent, reflecting the lower supply costs and relative abundance of attractive prospects in these countries.

3.4.3 Alternative Resource Scenarios

Projected production levels are also very dependent on the assumptions made regarding each supply region's remaining undiscovered resource base. The level of undiscovered oil is a critical element in the calculation of finding rates, as illustrated in Section 3.4. Figure 3.11 compares potential time paths of non-OPEC crude oil production under a constant $17.50 per barrel crude price for three resource scenarios, using the ranges of remaining undiscovered resources provided in Table 3.7. Under the optimistic scenario (5 percent probability level), total non-OPEC production peaks at 25 MMb/d in 1992 compared to 23.2 MMb/d in 1991 under the modal case. A steady decline in production is projected under the pessimistic (95 percent probability level) scenario. By the year 2000, production falls to 16.0 MMb/d compared to 19.4 and 23.6 MMb/d under the modal and optimistic scenarios, respectively.

These projections illustrate some of the inherent uncertainty in attempting to project future crude oil supplies. However, given the steady upward trend in estimates of the world's crude oil resources over the years, we feel that it is quite safe to disregard the pessimistic scenario. Indeed, although the modal resource scenario is the one utilized to do most of the

Figure 3.11
Projected Non-OPEC Oil Production Under Three Resource Scenarios



SOURCE: Canadian Energy Research Institute.
Note: Projections based on flat $17.50 per barrel crude oil price over the forcast period.

price projections in Chapter 4, it is entirely possible that the supply projections made under the optimistic scenario will bear the closest resemblance to the levels we will actually see in the future.

Footnotes

[1] The authors of this study would like to acknowledge the contribution of James N. Tanner, Research Associate, CERI, to the development of the supply side methodology employed in the World Oil Market model.

[2] Unless otherwise noted, all crude oil prices referenced in this chapter are in nominal U.S. dollars.

[3] Ahmed Zaki Yamani, Oil Markets: Past, Present, and Future, address delivered to the John F. Kennedy School of Government (Cambridge, Massachussetts: Harvard University, 1986), p. 11.

[4] A netback crude contract determines the eventual prices to be paid for a cargo of oil by calculating the market value of the petroleum products that will subsequently be refined from that oil. In essence, a netback agreement recreates the economics of the petroleum refining industry in order to guarantee a downstream margin for the crude purchaser. When the Saudi's adopted netback contracts to boost output, other oil producers undercut by the Saudi marketing strategy had to match the terms of the netback contracts, either by introducing netbacks of their own or by offering equally attractive terms in other forms of contracts. By the summer of 1986, some 40 to 50 percent of total world oil trade was conducted on netback terms. For a concise description of netback pricing and its impact on the world oil market, see Canadian Energy Research Institute, World Oil Market Analysis, Vol. IV, no. 4 (October 1986), pp. 6 - 9.

[5] Some examples of Canadian based models include, Brian L. Scarfe and Edwin W. Rilkoff, Financing Oil and Gas Exploration and Development Activity, Discussion Paper No. 274, (Ottawa: Economic Council of Canada, December 1984); S. Madduri and J. N. Tanner, "A Petroleum Activity Model," Alberta Energy and Natural Resources Working Paper (Edmonton: September 1983); Peter C. Bing and John Gillies," A Model of Exploration Drilling Activity," paper presented to the Ninth International Conference of the International Association of Energy Economists in Calgary, July 1987; and Abba Bhargava, "Saskatchewan Disaggregated Drilling Model," paper presented to Saskatchewan Department of Energy and Mines, 1987.

[6] Two excellent reviews of these different types of methodologies are contained in, Morris A. Adleman, J. C. Houghton, G. Kaufman, and M. Zimmerman, Estimation of Resources and Reserves, report prepared for the Electric Power Research Instititе (Palo Alto: 1982); and Mathtech, Incorporated, Comparative State-of-the-Art Assessment of Oil Supply Modelling, report prepared for the Electric Power Research Institute (Palo Alto: 1978).

[7] M. King Hubbert, "Degree of Advancement of Petroleum Exploration in United States," The American Association of Petroleum Geologists Bulletin, Vol. 51/11 (November 1967).

[8] Hubbert chooses a logistic function--which exhibits these basic characteristics as a life cycle model. We have modified this model so that cumulative discoveries become a function of cumulative drilling effort rather than time.

[9] These sources include, C. D. Masters, D. H. Roots, and W. D. Dietzman, "Distribution and Quantiative Assessment of World Crude Oil Reserves and Resources," Eleventh World Petroleum Congress, Volume 2 (1983) pp. 229-237; U.S. Department of Energy, Energy Information Administration, Foreign Energy Supply Assessment Series, Various Publications; Geological Survey of Canada, Conventional Oil Resources of Western Canada, paper 87-26 (Ottawa: Minister of Supply and Services, 1988); U.S. Department of the Interior, Geological Survey Circular 860, Estimates of Undiscovered Recoverable Conventional Resources of Oil and Gas in the United States, (Washington: 1981).

[10] Wood, MacKenzie and Co., "Section 2 of the North Sea Service," (Edinburgh: June 1976).

[11] Wood, MacKenzie and Co. have estimated operating costs for the major fields in the U.K. North Sea. See Oil and Gas Journal, Feb. 17, 1986, p. 25.

[12] See M. A. Adleman, "The Competitive Floor to World Oil Prices," The Energy Journal, Vol. 7, no. 4 (October 1986), p. 13, for a simple derivation of this model.

[13] Ibid., pp. 13-14.

[14] These assumptions for refinery gain and net CPE exports are consistent with those employed by the International Energy Agency. See International Energy Agency, Long-term Energy Outlook, Mimeo (Paris: International Energy Agency, 1988).

[15] A large part of this discussion is taken from, Canadian Energy Research Institute, World Oil Market Analysis, Vol. VI, no. 2 (April 1988) pp.5-10.

[16] Supply costs and development profiles for Canadian frontier reserves were based on assumptions employed in two CERI studies, K. Morgan MacRae, An Assessment of the Potential for Coal-Derived Syncrudes in Canada, Study No. 27 (Calgary: Canadian Energy Research Institute, June 1988); and W. H. Ingram and J. N. Tanner, Canadian Crude Oil Supply/Demand Balances: Projections to 2010, Forthcoming Release (Calgary: Canadian Energy Research Institute).

[17] Canadian Energy Research Institute, World Oil Market Analysis, Vol. VI. no. 2 (April 1988), p. 8.

Chapter 4

EVOLUTION OF THE WORLD OIL MARKET: REFERENCE CASE AND ALTERNATIVE MARKET SCENARIOS

4.1 Introduction

The preceding chapters have provided an analysis of the market fundamentals which will determine the path of crude oil prices over the medium and long term. The incorporation of these fundamentals in the demand and supply components of the CERI World Oil Market model have been described in some detail, and sensitivity cases discussed to indicate the responsiveness of crude oil demand and supply to changes in the key variables underlying the model.

In this chapter, we bring the supply and demand sides of the model together. We briefly describe the solution procedure of the integrated analytical framework and discuss in some detail the reference crude oil market scenario resulting from our research. The reference scenario reflects the combined judgement of the study authors as to the most likely path for crude oil prices, given a rational and well-behaved market and the absence of unknown supply and demand shocks.

As with all exercises in forecasting, it is highly likely that events will arise that will shock the market off of this reference or most-likely track; given the volatility of the world oil market over the past 15 years, this would seem almost inevitable. Therefore, we have selected six alternative scenarios based on possible and plausible future events which could impact on the evolution of the world oil market, and provide a discussion of the likely impacts relative to our selected reference case. These alternative scenarios not only emphasize the flexibility and range of analysis built into the CERI World Oil Market model, but also underline the importance of such an analytical framework for gauging the direction and magnitude of impact resulting from such events.

4.2 The Integrated World Oil Market Model

Chapters 2 and 3 described the basic structure and key assumptions underlying the World Oil Demand and Supply models. Projections of total world oil demand are built up from regionally based forecasts disaggregated by refined product (see Section 2.4). The key data inputs required to implement the demand model include world oil prices, GDP growth rates for the seven regions contained in the model, and price and income elasticities to portray the response of product demand to changes in price and economic growth in each of these regions.

Projections of world oil production are also built up from the regional level. However, it is necessary that this component embody the existing market structure of oil producing nations. Essentially, a country is assumed to either be a member of the competitive fringe or of OPEC. Supply projections (based on the methodology discussed in Section 3.4) are generated for those regions in the competitive fringe, as it is reasonable to assume that these countries are price-takers--that is, that their drilling and production programs are predicated on prevailing and expected prices and that they have little power in setting prices. The only exogenous variables required to generate projections of non-OPEC crude oil production are world oil prices and interest rates, the two primary drivers of drilling activity. However, in building up a picture of total non-OPEC oil supplies, liquids production in the CPEs and world NGL production must be provided as exogenous variables (see Section 3.5).

Each of these components of the World Oil Market model can be implemented on a stand-alone basis simply by specifying the required data inputs as described above and in Chapters 2 and 3. While this in itself serves a valuable role in examining the potential evolution of world oil demand or supply, the primary motivation in their construction was to create a system capable of generating consistent projections of either one of two critical variables:

- world oil prices, defined to represent West Texas Intermediate (WTI) prices at Cushing, Oklahoma; or
- OPEC production levels, which represent total cartel crude oil production.

As OPEC has become all too aware, the cartel is unable to consistently set both prices and production levels; one determines the other. Below we describe the two simulation modes of the integrated World Oil Market model, each representing one of the two paths available to OPEC in its attempt to control price movements on the world oil market.

4.2.1 Price Projection Mode

The perspective adopted in this mode is that OPEC sets and adheres to a quota for total cartel production, and then allows competitive market forces to determine oil prices. The is the strategy that has been adopted by OPEC since early 1988, when the cartel abandoned (in practice) its schedule of fixed prices for crude oil exports. Figure 4.1 provides a simple flow diagram of this process. Obviously, the most crucial assumption required here is the hypothesized level of OPEC production over the forecast horizon. As noted above, it is feasible to develop a model to forecast crude oil production in the competitive fringe. However, any similar attempt to forecast cartel production is fraught with complexities, as future output levels will be highly dependent on a combination of strategic, political and sociological factors which are virtually impossible to capture in an economic framework.

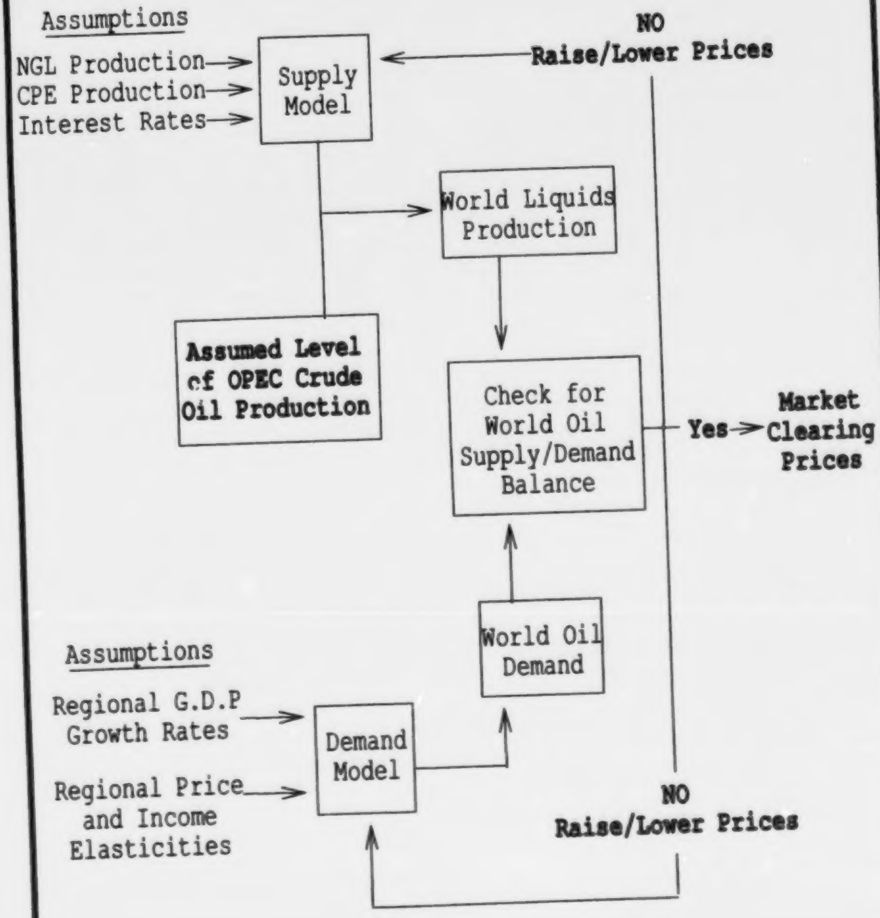
In our view, the high degree of uncertainty regarding future cartel production levels is best resolved by incorporating within the model framework the flexibility to deal with an array of potential scenarios. For example, analysts have expressed sharply different views about the impact of the cessation in hostilities between Iran and Iraq. Some feel that after a cease-fire is concluded, it will be followed by a period of over-production for some years as both countries attempt to rebuild their decimated economies. Others hold the opinion that the end of the war will result in a more cohesive OPEC, as Saudi Arabia and Kuwait cease their support of Iraq (through Neutral Zone production) and Iraq is pressured to adhere to a reasonable production quota. By requiring OPEC production levels to be exogenously specified, key uncertainties such as these (along with a wide range of other plausible and interesting scenarios) can be analyzed and compared in a consistent and detailed manner.

Once OPEC production levels are set over the forecast horizon--either by individual country or for the cartel as a whole--future prices are determined using a recursive solution routine. Given an initial price level, total world oil demand and supply are calculated, and the resulting supply/demand balance is checked against a convergence criteria. If excess demand (supply) is detected the price is raised (lowered) according to the degree of imbalance. This procedure is repeated until convergence between supply and demand is reached. The resulting level of prices and volumes--what we term "market clearing" prices and volumes--is the model output described later on in this chapter.

4.2.2 OPEC Production Mode

Alternatively, OPEC members could potentially set a desired price level and subsequently take whatever share of the market is left to them at those fixed prices. Realistically, this is a much more difficult strategy to follow, given the wide range of crude types produced in the member countries

Figure 4.1
The Price Projection Mode Of The
World Oil Market Model


Assumptions
NGL Production
CPE Production
Interest Rates
Supply Model
NO
Raise/Lower Prices
World Liquids Production
Assumed Level of OPEC Crude Oil Production
Check for World Oil Supply/Demand Balance
Yes
Market Clearing Prices
World Oil Demand
Assumptions
Regional G.D.P Growth Rates
Regional Price and Income Elasticities
Demand Model
NO
Raise/Lower Prices

SOURCE: Canadian Energy Research Institute.

and the need to price each according to its particular qualities. As Figure 4.2 illustrates, this simulation mode is very similar to the price projection mode, except that instead of specifying OPEC production levels, an exogenous world oil price track must be provided over the forecast horizon. In this particular case, there is also no need for a recursive type of solution procedure, since OPEC production is calculated as the residual of world oil demand and non-OPEC oil production.

We do not make any attempt to allocate cartel production amongst the various OPEC member countries. Indeed, we see the primary use of this simulation mode as a quick check on the consistency of any "ad-hoc" type of oil price forecast. Glaring inconsistencies in such a forecast, such as unacceptably low levels of OPEC production, and their underlying causes can thus be quickly identified.

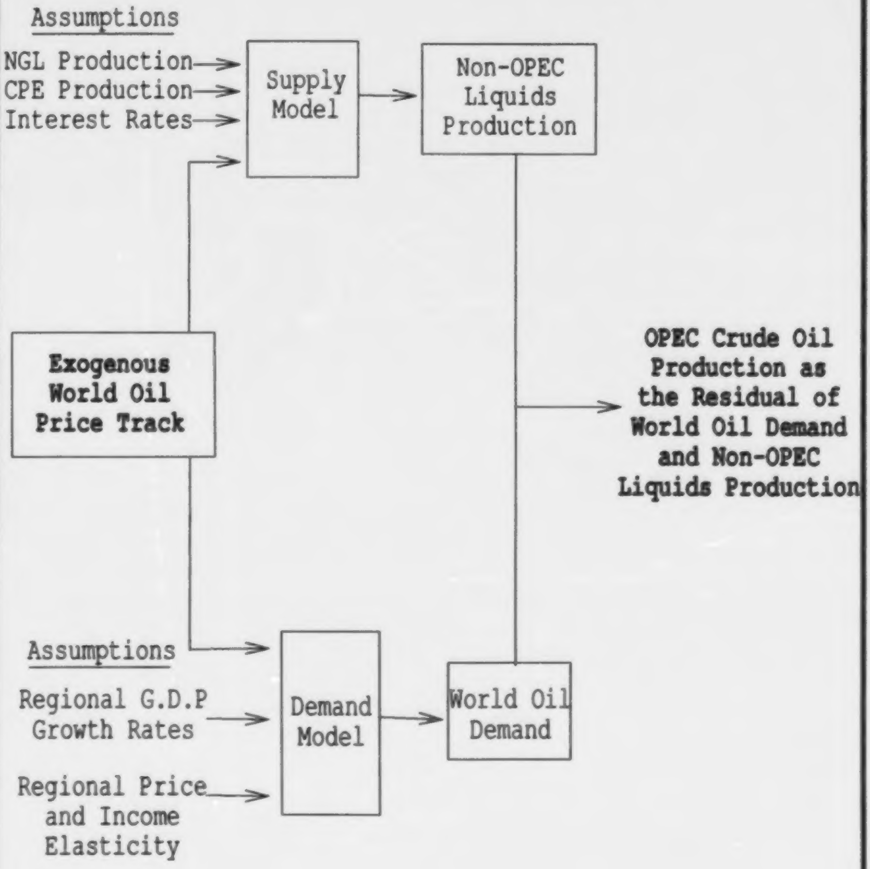
4.3 Reference Case Projection

"Volatility" is a catchword that has become all too familiar to world oil market analysts over the last 3 years. World oil prices refuse to follow a stable pattern, and price swings of more than $1.00 per barrel during a day have become commonplace. Effective planning and capital allocation in the oil industry requires that industry planners have a sound grasp of a price track that is most likely to occur in the future, and in which direction prices are likely to move, given plausible divergences from the assumptions which underlie this forecast.

This section presents the results of what we have termed the reference case. The term "reference" was chosen because the case embodies a very reasonable set of assumptions regarding OPEC production levels over time, non-OPEC supply potential, GDP growth rates around the world (these assumptions are provided in Appendix C for each demand region), and the responsiveness of oil demand to changes in price and GDP growth rates (the values assumed for speed of adjustment parameters and for price and income elasticities appear in Appendix B). The results were generated using the price simulation mode of the World Oil Market model and hence the reported prices and volumes represent annual average "market clearing" levels. Cases analyzed subsequently will show a range of possible outcomes for future prices in response to changes in certain key assumptions.

Table 4.1 provides a summary of some key indicators of world oil supply and demand over the last 3 years, to provide a benchmark for comparison with the reference case results. The salient pieces of information contained in the table are:

Figure 4.2
The OPEC Production Mode Of The World Oil Market Model


Assumptions
NGL Production
CPE Production
Interest Rates
Supply Model
Non-OPEC Liquids Production
Exogenous World Oil Price Track
OPEC Crude Oil Production as the Residual of World Oil Demand and Non-OPEC Liquids Production
Assumptions
Regional G.D.P Growth Rates
Regional Price and Income Elasticity
Demand Model
World Oil Demand

SOURCE: Canadian Energy Research Institute.

TABLE 4.1

WORLD OIL SUPPLY AND DEMAND
1986-1988
(MMb/d)

	Consumption			Supply							
Year	OECD	NOPEC	Total World[a]	OECD	NOPEC	Net CPE Exports	Total Non-OPEC[b]	OPEC Crude Production	OPEC NGL Production	Total OPEC	Total World[a]
1986	35.2	12.7	47.9	16.9	8.5	1.8	28.3	17.9	1.6	19.5	47.8
1987	35.7	13.0	48.7	16.8	8.9	2.1	28.9	17.7	1.7	19.4	48.3
Q1	36.3	13.0	49.3	16.9	8.8	1.6	28.4	15.6	1.7	17.3	45.7
Q2	34.3	12.5	46.8	16.5	8.8	2.0	28.4	16.9	1.7	18.6	47.0
Q3	35.5	13.0	48.5	16.6	8.9	2.4	29.0	19.2	1.7	20.9	49.9
Q4	36.9	13.4	50.3	17.0	9.0	2.3	29.4	18.9	1.7	20.6	50.0
1988											
Q1	37.5	13.3	50.8	17.1	9.2	1.6	29.0	17.5	1.7	19.2	48.2
Q2	35.0	12.8	47.8	16.8	9.2	2.0	29.1	18.5	1.7	20.2	49.3

SOURCE: International Energy Agency, Oil Market Report, July 1988.

[a] Excludes CPEs.
[b] Includes 1.1 MMb/d for refinery gain.

- OECD oil consumption in the first quarter of 1988 exceeded first quarter 1987 consumption by 1.2 MMb/d, an increase of 3 percent. Estimates for the second quarter of 1988 show a slightly lower rate of growth of about 2 percent, with consumption increasing by 700 Mb/d over the second quarter of 1987.

- Similar growth rates were recorded in the LDC countries, with consumption in the first and second quarters of 1988 growing by 300 Mb/d over 1987 levels.

- As a whole, non-OPEC oil consumption grew by 3.0 percent in the first quarter of 1988 over the first quarter of 1987, increasing from 49.3 MMb/d to 50.8 MMb/d. Growth was more modest in the second quarter with total consumption increasing to 47.8 MMb/d versus 46.8 MMb/d in the first quarter of 1987.

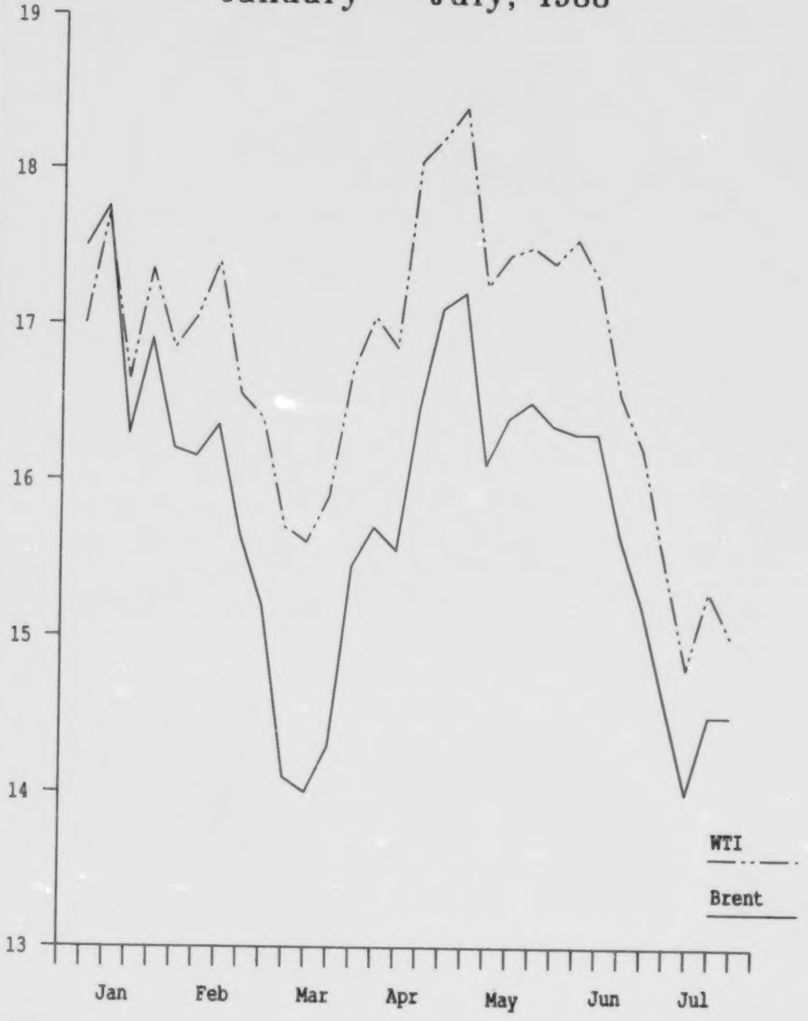
- Year-over-year production of total non-OPEC crude oil liquids grew by more than 2.0 percent in the first quarter of 1988, increasing from 28.4 MMb/d to 29.0 MMb/d. OECD countries contributed about 300 Mb/d to this growth--primarily due to higher North Sea and Canadian production--while increased production in Angola and North Yemen supplied most of the balance.

- OPEC crude oil production levels in 1988 are significantly higher than 1987 levels. First quarter 1988 production is estimated at 17.5 MMb/d, a 12 percent increase over the same period in 1987, while second quarter 1988 output is estimated to be more than 9.0 percent greater than 1987 levels, currently standing at close to 18.5 MMb/d.

Prices to date in 1988 generally reflect OPEC's persistent overproduction (see Figure 4.3). Recent months have seen the spot markets either anticipating the results of a forthcoming OPEC meeting or trying to assess the actual impact of one that has just occurred. Not surprisingly, the market is sending out confused and contradictory signals for which no clear explanation appears appropriate. Crude oil prices are generally sliding downhill, having fallen from \$17-\$18 per barrel to \$14-\$15 per barrel between January and June. The uncertainty in the market was clearly apparent following the announcement by Iran on July 20 that they would seriously consider the U.N. ceasefire resolution--prices immediately rose by more than \$1.00 per barrel before falling by \$0.80 per barrel within the next 3 days.

With this backdrop in place, the most crucial assumption required to project future prices--the level of OPEC production over the forecast horizon--is provided in Table 4.2. OPEC production is assumed to average 18.8 MMb/d in 1988, not an unreasonable assumption given that the cartel's

Figure 4.3
Selected Crude Oil Spot Prices
January - July, 1988



SOURCE: Petroleum Intelligence Weekly.

TABLE 4.2

REFERENCE CASE OPEC PRODUCTION
1987-2000

Year	Annual Daily Average (MMb/d)	Annual Change (%)
1987	17.7	-1.1
1988	18.8	6.2
1989	19.3	2.7
1990	19.5	0.8
1991	19.8	1.8
1992	20.4	3.0
1993	21.3	4.4
1994	22.0	3.3
1995	22.8	3.6
1996	23.6	3.5
1997	24.4	3.4
1998	25.4	4.1
1999	26.4	3.9
2000	27.4	3.8

SOURCE: Canadian Energy Research Institute.

production has averaged 18.0 MMb/d over the first two quarters of 1988 and production is traditionally greater in the last two quarters of the year. Between 1989 and 1991 the ability, and desire, of the cartel to increase production is assumed to be mitigated by increases in non-OPEC production. During this period, the cartel's average annual daily output is assumed to grow by less than 2.0 percent per annum. The premise here is that OPEC will be averse to a fall in prices and will exhibit sufficient discipline to hold the line on production increases. After 1991, the cartel is assumed to be in a better position to take advantage of world oil demand growth and stagnant non-OPEC output. Through to the end of the forecast horizon, the cartel expands production at an average rate of roughly 3.5 percent per annum. By the year 2000, OPEC crude oil production reaches 27.4 MMb/d, a level that is 46 percent higher than today's output but significantly below the cartel's current productive capacity of about 34 MMb/d.[1]

Table 4.3 provides a summary of the reference case results. Remembering that these results are conditional on the assumed level of OPEC production, the price trajectory shown in the table represents a readily sustainable path. The principal trend in the projected price movement is of a slow rise in prices through to the mid-1990s at an average per annum growth rate of slightly less than 3 percent, followed by slightly accelerated price increases at a 3.7 percent average annual rate of increase over the remaining years of the forecast horizon. Prices reach $22.50 per barrel by 1995 and $26.90 per barrel by the year 2000. However, the potential for some near term growth in prices is identified. Prices increase an average of 5.2 percent per annum between 1988 and 1990, from $17.50 per barrel in 1988 to $18.50 and $19.40 per barrel in 1989 and 1990, respectively.

This near-term growth in prices is made possible by increased levels of world oil consumption over the period, triggered largely by the steady fall in prices over the last 5 years. Oil consumption outside the CPEs is projected to increase by more than 1.0 MMb/d between 1987 and 1990. Rising real prices dampen the rate of growth in consumption to less than 1.0 percent per annum through the mid-1990s. From 1995 to the end of the century, growth in consumption is expected to strengthen slightly to about 1.1 percent per annum as the dampening effects of rising oil prices are more than offset by continued economic growth. By the year 2000, non-CPE oil consumption is expected to reach 54.5 MMb/d.

Projections of total world oil consumption by refined product are shown in Table 4.4. Gasoline exhibits the strongest demand growth of the refined products, averaging about 1.6 percent per annum over the forecast horizon. This is largely due to a lack of viable alternative fuels and to lower rates of price increases than the other products, since a given increase in the

TABLE 4.3

REFERENCE CASE MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S.)	World Demand (MMb/d)	World Supply (MMb/d)	Non-CPE Demand (MMb/d)	Non-CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.63	62.12	61.54	48.67	45.85	2.24
1988	17.50	63.26	62.97	49.62	47.16	2.17
1989	18.54	64.00	64.00	50.19	47.99	2.20
1990	19.40	64.59	64.58	50.59	48.36	2.22
1991	19.82	65.23	65.23	51.04	48.92	2.12
1992	20.69	65.80	65.79	51.40	49.59	1.81
1993	21.06	66.44	66.48	51.85	50.39	1.50
1994	21.78	67.06	67.05	52.24	50.93	1.30
1995	22.53	67.70	67.69	52.63	51.53	1.10
1996	23.65	68.25	68.25	52.94	52.04	0.90
1997	24.69	68.78	68.78	53.23	52.54	0.70
1998	24.99	69.47	69.47	53.69	53.19	0.50
1999	26.15	70.10	70.14	54.08	53.87	0.25
2000	26.90	70.78	70.77	54.52	54.51	0.00

SOURCE: Canadian Energy Research Institute.

TABLE 4.4

WORLD OIL DEMAND BY PRODUCT
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,393	20,216	11,817	13,697	62,124
1988	16,762	20,586	12,088	13,823	63,260
1989	17,064	20,797	12,196	13,945	64,003
1990	17,335	20,935	12,235	14,083	64,589
1991	17,619	21,084	12,280	14,251	65,232
1992	17,888	21,191	12,290	14,431	65,798
1993	18,164	21,324	12,326	14,627	66,440
1994	18,430	21,442	12,353	14,831	67,057
1995	18,704	21,558	12,381	15,051	67,695
1996	18,967	21,633	12,378	15,275	68,254
1997	19,222	21,690	12,364	15,502	68,777
1998	19,506	21,813	12,405	15,750	69,474
1999	19,779	21,901	12,419	16,001	70,100
2000	20,063	22,009	12,450	16,260	70,780

SOURCE: Canadian Energy Research Institute.

crude oil price translates into a smaller end-use price increase for gasoline due to higher taxes and refining costs. Heavy fuel oil consumption is projected to be essentially flat over the forecast period, reflecting the vigorous interfuel competition it faces through the 1990s from natural gas, electricity and coal.

On a regional basis (see Table 4.5), the LDCs and OPEC contribute the largest share to world demand growth, with oil consumption projected to increase at an average rate of 2.0 and 2.5 percent per annum, respectively. Consumption in the CPEs is also projected to grow quite vigorously at an average rate of 1.6 percent per annum. A more modest growth rate of 0.6 percent per annum is expected in the OECD countries, led by the U.S. with its burgeoning gasoline consumption. Of the 8.0 MMb/d increase in world oil consumption projected to occur by the year 2000, OPEC and the LDCs contribute 1.4 and 2.8 MMb/d respectively, the CPEs contribute another 3.0 MMb/d, while the combined OECD countries add only 2.0 MMb/d. Those readers interested in greater detail can refer to Appendix E which provides demand projections by product for each of the seven demand regions.

Table 4.6 provides a summary of the projections of world crude oil and NGL production. As noted above, OPEC is assumed to increase its crude oil output steadily over the forecast horizon, from 18.8 MMb/d in 1988 to 27.4 MMb/d by the year 2000. NGL production in the cartel countries is assumed to grow from 1.4 MMb/d in 1988 to 2.0 MMb/d by the end of the century. Projections for non-OPEC countries (excluding CPEs) are based on the assumption that they produce at productive capacity unless the price falls below operating cost, which it does not in this case. Combined crude oil output in these countries is projected to average 23.0 MMb/d in 1988, crest at 23.7 MMb/d in 1992, and decline to 21.3 MMb/d by the end of the forecast horizon. Total NGL production outside of OPEC is assumed to remain essentially flat, falling only slightly from 2.8 MMb/d to 2.7 MMb/d between 1988 and 2000.

The reader is referred to Section 3.5.1.1 for a detailed country-by-country breakdown of these supply projections. Appendix E provides country-specific information on projected drilling activity, finding rates, reserves additions and production.

The first key result to note is a significant decline in OECD crude oil production, from 16.7 MMb/d in 1987 to 13.9 MMb/d in 2000. This decline is centered in the U.S. and the North Sea which each see production fall by about 23 percent by the end of the forecast horizon. Canadian production is projected to fall by 17 percent over the same period. Considerable frontier production is expected to come on stream beginning in the mid-1990s,

TABLE 4.5

WORLD OIL DEMAND BY REGION
1987-2000
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECD	Less Developed Countries	OPEC	Central Planned Economies	Total World
1987	1,500	16,532	12,198	5,066	9,628	3,744	13,455	62,124
1988	1,505	16,878	12,423	5,118	9,876	3,816	13,644	63,260
1989	1,503	17,061	12,516	5,141	10,091	3,879	13,811	64,003
1990	1,503	17,156	12,538	5,155	10,288	3,947	14,002	64,589
1991	1,505	17,272	12,560	5,178	10,497	4,028	14,193	65,232
1992	1,507	17,349	12,543	5,197	10,690	4,118	14,394	65,798
1993	1,513	17,440	12,549	5,225	10,897	4,221	14,595	66,440
1994	1,517	17,504	12,538	5,244	11,103	4,331	14,820	67,057
1995	1,524	17,572	12,520	5,261	11,304	4,450	15,065	67,695
1996	1,529	17,620	12,473	5,265	11,484	4,572	15,311	68,254
1997	1,532	17,662	12,416	5,271	11,655	4,699	15,544	68,777
1998	1,541	17,757	12,406	5,297	11,855	4,838	15,780	69,474
1999	1,548	17,828	12,368	5,315	12,038	4,981	16,021	70,100
2000	1,559	17,916	13,343	5,339	12,231	5,132	16,260	70,780

SOURCE: Canadian Energy Research Institute.

TABLE 4.6

WORLD CRUDE OIL PRODUCTION SUMMARY
1987-2000
(Mb/d)

Year	Total	OPEC		CPE	Non-OPEC		Total Non-OPEC Liquids Production
		Crude Oil	NGLs		Crude Oil	NGLs	
1987	61,540	17,700	1,408	15,695	22,825	2,811	25,636
1988	62,969	18,800	1,443	15,810	23,017	2,798	25,815
1989	63,996	19,300	1,479	16,010	23,321	2,785	26,107
1990	64,581	19,450	1,516	16,220	23,520	2,774	26,295
1991	65,225	19,800	1,554	16,310	23,696	2,764	26,461
1992	65,790	20,400	1,593	16,200	23,741	2,755	26,496
1993	66,478	21,300	1,633	16,090	23,607	2,747	26,354
1994	67,049	22,000	1,675	16,120	23,413	2,740	26,153
1995	67,686	22,800	1,718	16,160	23,174	2,733	25,908
1996	68,245	23,600	1,762	16,210	22,844	2,728	25,573
1997	68,783	24,400	1,807	16,240	22,511	2,723	25,235
1998	69,466	25,400	1,854	16,280	22,110	2,720	24,831
1999	70,143	26,400	1,903	16,270	21,753	2,717	24,470
2000	70,771	27,400	1,952	16,260	21,341	2,716	24,058

SOURCE: Canadian Energy Research Institute.

partially offsetting a more rapid decline in conventional production. Second, this decrease in OECD production is somewhat offset by a sizable expansion in the output of the LDC countries. Crude oil production in these countries is projected to increase from 8.9 MMb/d to 10.2 MMb/d over the same period. Mexico, North and South Yemen, Malaysia, Brazil and Colombia are expected to provide the bulk of this added output.

Production in the CPEs is assumed to remain relatively flat over the forecast horizon at close to 16.0 MMb/d. Although this is not an unreasonable assumption, the primary motivation in choosing this level was to drive net CPE exports to zero by the year 2000.[2] Our understanding of energy demand in these countries is limited by a lack of reliable information, so that the demand projection discussed earlier is highly uncertain. More than anything, future levels of net-CPE exports are likely to reflect government policies calling for some degree of demand management--such as the promotion of a gradual transition to natural gas, which is relatively abundant and more difficult to export in large quantities--and the meeting of state production and foreign exchange targets.

The implications that the reference case holds for OPEC revenues are outlined in Tables 4.7 and 4.8. The calculation of the annual revenue stream likely to accrue to the cartel is considerably simplified. Projected prices are multiplied by the assumed level of OPEC production, ignoring any differences in the actual prices which the various member countries would receive due to differentials in crude quality and transportation costs. Given these assumptions, OPEC's annual revenue stream can be expected to more than double in real terms over the forecast horizon, increasing from about $120 billion in 1988 to over $260 billion in 2000. In present value terms, if OPEC was to adhere to the production levels assumed in this case, it could potentially realize some $1.2 trillion from crude oil sales (assuming a 10 percent rate of discount).

It is our view, supported by our analysis of the subsequent sensitivity scenarios, that this reference case and the associated price projection provide a very realistic picture of future world oil market developments. The level of crude oil production assumed for OPEC does not require that the cartel reduce quotas from current levels in the near term and should be attainable given a reasonable degree of cartel unity. Although prices increase quite modestly over the forecast period, steady demand growth and an eventual decline in non-OPEC production will allow the cartel to gradually increase both its market share and annual revenue.

In summary, the reference case projection is dependent on a rational and patient OPEC, willing to establish and abide by reasonable

TABLE 4.7

ANNUAL OPEC REVENUE STREAM
(billions of $1987 U.S.)

Year	Oil Revenue
1987	120
1988	120
1989	130
1990	137
1991	143
1992	154
1993	163
1994	174
1995	187
1996	203
1997	219
1998	231
1999	252
2000	268

SOURCE: Canadian Energy Research Institute.

NOTE: OPEC revenue calculations based on production quota volumes shown in Table 4.3.

TABLE 4.8

PRESENT VALUE OF REVENUE FROM OPEC CRUDE OIL PRODUCTION
(billions of $1987 U.S.)

Discount Rate	Present Value of OPEC Revenue Stream
5%	1684
10%	1195
15%	889

SOURCE: Canadian Energy Research Institute.

NOTE: OPEC revenue calculations based on production quota volumes shown in Table 4.3.

production quotas. The share of total crude oil liquids production accruing to the cartel members increases from roughly 31 percent in 1987 to over 41 percent by the year 2000. Attempts to further raise the price of crude oil in the short term will be met by renewed exploration, development and production of conventional reserves in the non-OPEC countries (as well as the accelerated development of nonconventional crude oil sources such as coal liquefaction, offshore reserves, tar shales and tar sands, and the aggressive pursuit of enhanced oil recovery projects). As discussed in the next section, attempts to increase production in the short-term may also prove counterproductive, due to the sensitivity of crude oil prices to increased world production. In most respects, this reference case represents a best-case scenario for OPEC, in terms of discounted revenue flow accruing from crude oil production.

4.4 Alternative Scenarios

The reference scenario discussed above is based on a rational market approach by the OPEC cartel and the absence of shocks to the market. As mentioned above, the volatility of the world oil market over the past 15 years suggests that these assumptions will almost certainly be violated over the next 15 years. Indeed, one of the principal challenges facing energy planners and policy-makers is to anticipate the direction and timing of these shocks, and to gauge the magnitude of market response to these disruptions.

The CERI World Oil Market model provides a most useful framework for analyzing various possible shocks to the world oil market. This section looks at six plausible alternative scenarios, comparing them to the reference case results described above, and provides the reader with an appreciation of the potential impact of these possible changes in the world oil market structure. Table 4.9 provides a brief summary of the alternative scenarios examined in this section.

4.4.1 Competitive Market Scenario

The trials and tribulations experienced by OPEC in recent years have focussed considerable attention on the likelihood and potential consequences of OPEC's complete dissolution. What would happen to oil prices if OPEC unity broke down altogether, so that world oil trade once again was carried out on a more-or-less competitive basis? A number of both qualitative and quantitative studies have attempted to address this question,[3] especially since the crude oil price crash of 1986 sent shock waves through the global oil industry and left many producers wondering just how far prices could fall.

TABLE 4.9

ALTERNATIVE MARKET SCENARIOS

Scenario Title	Scenario Description
Competitive Market Scenario	Dissolution of OPEC in 1989, followed by a gradual return of all OPEC countries to previous peak output levels (complete by 1993) and a 1 MMb/d addition to combined capacity per year to the year 2000.
"GOPEC" Scenario	Dissolution of OPEC in 1989, with a new, four-nation mini-cartel (Saudi Arabia, Kuwait, Qatar and the U.A.E.) restraining production to maintain prices at $15 (U.S.) per barrel, in constant 1987 dollars.
OPEC Market Manipulation Scenario	OPEC manipulates production quotas to generate a series of price spikes (up and down) to maximize cartel revenue while deterring further development of non-OPEC conventional and nonconventional crude oil resources.
High Resource Scenario	Higher ultimate potential reserves estimate (5 percent probability level) assumed for all non-OPEC producing nations.
U.S. Import Fee Scenario	Domestic U.S. crude oil price set at a floor of $25 per barrel ($1987 U.S.) effective in 1989; all crude produced in, or imported into, the U.S. is priced at a flat $25 per barrel until the world price exceeds this floor price.
Alternative Economic Growth Scenario	Economic growth in the OECD countries set equal to zero in 1989 and 1990, reference case levels thereafter; economic growth in the LDCs set at 5.0 percent (versus 3.5 percent in the reference case) for the period 1990-2000.
High CPE Net Exports Scenario	Chinese net crude oil exports decline to zero by 1992, but Soviet net exports are maintained at their current level of 1.7 MMb/d through the forecast period.

SOURCE: Canadian Energy Research Institute.

The question of the competitive floor price of crude oil is of more than academic interest. Some analysts suggest that the recent decade of high, cartel-supported oil prices was but a short aberration from a long-term trend of low real prices (as illustrated, for example, in Figure 1.8). If oil markets continue their recent movement towards deregulation, deintegration, and more open and flexible competition, then perhaps a return of oil prices to those low historical levels is indeed most likely. Even if OPEC does not completely collapse, it is possible that periodic crises within the organization might lead to severe upward and downward price spikes. An understanding of the likely competitive price of oil provides some indication of a lower limit to these price fluctuations.

OPEC itself has evolved through several different forms since its inception in 1960. Prior to 1971, the organization was a relatively powerless lobby group, attempting to negotiate better terms on such matters as concession agreements and production practices with the large multinational corporations that dominated oil trade at the time. With the famous Teheran-Tripoli Agreement of 1971, however, the cartel set its sights on reversing the steady decline in real oil prices that had occurred since the mid-1950s. This effort paid off magnificently in 1973-1974 and again in 1979-1980, as OPEC took advantage of international political developments to successfully press its demand for a higher return for its members' massive crude oil reserves.

Later, in the early 1980s, this focus on price-fixing was replaced with a new concentration on limiting the production of OPEC members. In 1981, OPEC began to experiment with its first production quotas, in a rear guard action to defend high oil prices against declining demand for OPEC crude. Saudi Arabia was exempted from the first production quotas in explicit recognition of its role as a swing producer, making up the difference between the output of the other producers and total world demand. Today, this production quota system is the primary form of OPEC's intervention in world oil trade. The cartel's 1987 attempt to re-instate fixed official prices for its oil exports was essentially abandoned in the early spring of 1988, following stiff buyer resistance, slumping spot prices, and widespread under-the-table discounts offered by several OPEC members. OPEC's quota system is a source of continual conflict within the organization over issues such as chronic overproduction and the definition of production, but it has nevertheless allowed OPEC to restrain total output to less than 60 percent of historical capacity.

If OPEC were to fall apart, then, the impact on world oil markets would be felt first and foremost through the collapse of the quota system. Oil prices would plunge as OPEC producers abandoned their collective restraint and boosted production to capacity. The major difficulty in simulating such a collapse of OPEC is encountered in trying to estimate OPEC's productive capacity. The historical output peak for each country--reached by most OPEC members in the 1979-1981 period--is generally used as an indication of productivity from current developed reserves.[4] Such an estimate would tend to be inaccurate in the short run (1-2 years), however, because some time would be required to repair and refurbish unused production equipment, pipelines, loading facilities, etc. It would furthermore tend to understate OPEC productivity in the longer run, since new capacity could be added relatively easily from already proven but undeveloped reserves in most OPEC countries.

The estimates of OPEC capacity that we have used for our competitive market simulation are illustrated in Tables 4.10 and 4.11. For production from existing developed reserves, it is assumed that it would take 3 years for most OPEC members to regain their maximum historical levels of output. Saudi Arabia and Kuwait would take 4 years to reach capacity because of the sheer volume of their shut-in reserves, while Iran and Iraq would take 5 years because of the time and cost involved in repairing war-damaged production and transportation facilities.[5] On the basis of this schedule, a breakdown of OPEC in early 1989 would result in an historical peak level of OPEC production of some 33.4 MMb/d being reached by 1993 (see Table 4.10). In subsequent years, we assume that OPEC adds an additional 1 MMb/d of capacity per year--three-quarters of this in the reserves-rich Persian Gulf nations of Saudi Arabia, Kuwait, the U.A.E. and Qatar (sometimes referred to as the Gulf OPEC or "GOPEC" nations), and the remainder in the other OPEC countries (see Table 4.11).

The effects of OPEC's breakdown on world oil markets would be dramatic, as illustrated in Figures 4.4 and 4.5, and described in detail in Appendix F1. The real world price of oil quickly falls to an average of just over $11 (U.S.) per barrel in 1989, with further decreases of one dollar per barrel in each of 1990 and 1991. The projected price remains in the $9 to $10 range during 1992, as OPEC's full historical capacity is approached. In 1993, after four consecutive years of very low oil prices, a huge surge in world oil consumption becomes the dominant feature of world oil trade, and oil prices begin to slowly recover. Prices rebound to an average $12 (U.S.) per barrel in real terms by 1993, with further increases to over $16 by the end of the century. Between 1993 and 2000, further increases in OPEC production are more than offset by the dramatic increase in global consumption, which soars to an astounding 80 MMb/d by the end of the century. The result is that prices slowly increase through the last part of the 1990s, despite the flood of oil on the market.

TABLE 4.10

ESTIMATED OPEC PRODUCTIVE CAPACITY FROM
EXISTING DEVELOPED RESERVES[a]
1988-1993
(MMb/d)

	Saudia Arabia and Kuwait	Iran	Iraq	U.A.E. and Qatar	Libya and Algeria	Venezuela and Ecuador	Nigeria and Gabon	Indonesia	Total OPEC
1988[b]	5.6	2.1	2.6	1.5	1.6	1.9	1.5	1.2	17.7
1989	7.8	2.9	2.6	2.0	2.3	2.0	2.0	1.4	22.7
1990	9.4	3.6	2.8	2.2	2.6	2.3	2.2	1.5	26.2
1991	11.0	4.2	3.0	2.4	3.0	2.5	2.4	1.7	30.0
1992	12.6	4.9	3.3	2.4	3.0	2.5	2.4	1.7	32.5
1993	12.6	5.5	3.5	2.4	3.0	2.5	2.4	1.7	33.4

SOURCE: Canadian Energy Research Institute.

[a] Assumes breakdown of cartel in early 1989. Totals may not add due to rounding.
[b] Actual production over first six months.

TABLE 4.11

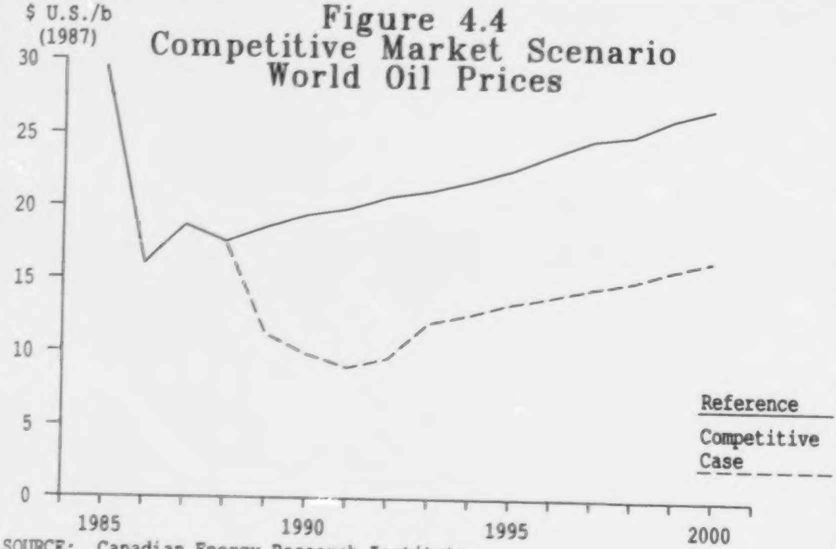
ESTIMATED OPEC PRODUCTIVE CAPACITY FROM EXISTING AND NEW RESERVES[a]
1988-2000
(MMb/d)

Year	Total OPEC	"GOPEC"[b]
1988[c]	17.7	7.1
1989	22.7	9.8
1990	26.2	11.6
1991	30.0	13.4
1992	32.5	15.0
1993	33.4	15.0
1994	34.4	15.8
1995	35.4	16.5
1996	36.4	17.3
1997	37.4	18.0
1998	38.4	18.8
1999	39.4	19.5
2000	40.4	20.3

SOURCE: Canadian Energy Research Institute.

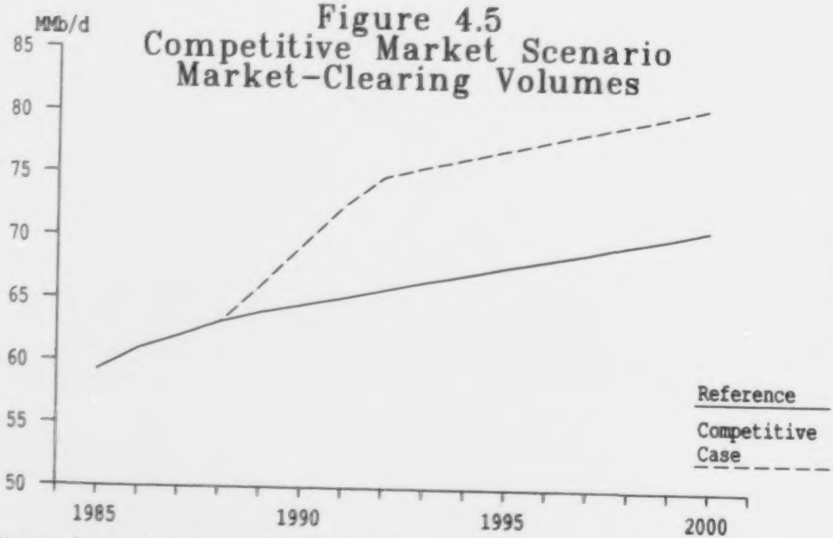
[a] Assumes breakdown of cartel in early 1989.
[b] "Gulf OPEC"; includes Saudi Arabia, Kuwait, the United Arab Emirates and Qatar.
[c] Actual production over first 6 months.

Figure 4.4
Competitive Market Scenario World Oil Prices



SOURCE: Canadian Energy Research Institute.

Figure 4.5
Competitive Market Scenario Market-Clearing Volumes



SOURCE: Canadian Energy Research Institute.

Dramatic as these developments are, our estimate of the competitive floor to world oil prices--about $9 (U.S.) per barrel in real 1987 terms--is somewhat higher than other estimates. Based on orthodox supply-curve analysis, some studies have suggested that the competitive price of oil could be as low as $3 to $5 per barrel, approximately equal to the costs of finding and producing marginal crude oil reserves in the low-cost Middle East. Our simulation suggests that by the time these massive reserves could be fully brought on-stream, the gigantic increases in demand resulting from rock-bottom prices would act to boost oil prices. If the OPEC taps could be turned open more quickly than we have suggested, or if the demand response to low prices were not as substantial, then the competitive price could prove to be even lower.[6]

The impact on non-OPEC supply of this dizzying price crash is severe. Total non-OPEC liquids production is forecast to fall by some 5 MMb/d between 1988 and 2000 under the competitive market scenario, an annual decline of some 1.5 percent. A virtual halt to most new exploration and development projects in high-cost non-OPEC regions is the main reason for this decline in output. Most existing non-OPEC production would continue to be produced even at prices as low as $9 (U.S.) per barrel; only very marginal and expensive fields in the U.S. and other mature basins would face the prospect of cost-induced shut-in under the competitive scenario.

The revenue implications for OPEC members of the cartel's collapse are severe, but again perhaps not as disastrous as might have been expected. On a net present value basis, OPEC's total revenue stream (in real 1987 dollars) between 1987 and 2000 is only about 15 percent lower in the competitive market scenario than it was in the reference case (see Table 4.12). The dramatic fall in prices under the competitive scenario is largely offset--for most OPEC members--by the equally dramatic increases in production volumes. The producing countries which would suffer the least in the competitive scenario are those with the most productive capacity currently shut-in. The "GOPEC" countries, for example, would receive present-value revenues in the competitive case of no more than 5 percent below their reference case receipts, thanks to their greatly expanded production. At lower discount rates, Saudi Arabia might actually receive more revenue under the competitive market scenario than in the reference case.

These results illustrate the powerful motive that the Persian Gulf nations possess for preserving moderate oil prices--their long-term interests are clearly better served by an expansion of volumes rather than by driving up the price in the near term. The countries which stand to lose the most from a break-up of OPEC and subsequent collapse in prices are those OPEC

TABLE 4.12

COMPETITIVE MARKET SCENARIO IMPLICATIONS FOR NET PRESENT REVENUE
1987-2000
(billions of $1987 U.S.)

Discount Rate	Total OPEC		GOPEC[a]		Saudi Arabia	
	Reference Case	Competitive Market	Reference Case	Competitive Market	Reference Case	Competitive Market
5%	1684.5	1453.5	678.0	668.2	420.2	432.8
10%	1195.1	1026.7	481.1	465.9	298.2	300.1
15%	889.8	762.6	358.2	341.7	222.0	218.8

SOURCE: Canadian Energy Research Institute.

[a] Includes Saudi Arabia, Kuwait, the United Arab Emirates and Qatar.

members--such as Indonesia, Algeria and Nigeria--which have much smaller volumes of shut-in capacity, as well as the non-OPEC producers which are currently producing at full capacity. For these countries, the devastating impact of falling prices would not be offset by increases in output.

Some analysts have suggested that in the event of a break-up of OPEC, the key Arab producers of the Persian Gulf would step in to prevent a complete collapse of oil prices. The "GOPEC" producers--Saudi Arabia, Kuwait, the U.A.E., Qatar and perhaps Iraq--are a more closely-knit group than OPEC as a whole, and would not face the same internal contradictions. They all enjoy huge reserves, small populations, and relatively healthy financial situations. They control enough of the world's oil supply to support world oil prices on their own, even if the rest of OPEC was producing at capacity. Would it be in the interests of this "cartel within a cartel" to stop oil prices from falling to the very low levels implied by a total collapse of OPEC?

CERI simulated a "GOPEC" scenario on the basis of a four-nation mini-cartel: Saudia Arabia, Kuwait, the U.A.E. and Qatar (see Figures 4.6 and 4.7). These nations restrain production in order to prevent the price from falling below $15 (U.S.) per barrel, in real 1987 terms. The other OPEC members (including Iraq) produce at capacity. It is only for the first 5 years following the collapse of OPEC that the GOPEC countries face severe production restraints; by 1995, GOPEC production starts to climb rapidly, and by the year 2000 they are producing at capacity like the rest of OPEC (see Table 4.13). The implications for OPEC revenue are summarized in Table 4.14. While revenue for OPEC as a whole is obviously higher in the case of GOPEC production restraint, for the GOPEC members themselves the strategy is counter-productive. In the event of a price collapse, it is the Persian Gulf nations that have the most to gain by opening up production to capacity. Their revenues are improved by producing at capacity, rather than by shouldering the burden of production restraint single-handedly to defend the price. Clearly, the other OPEC members need OPEC more than the reserves-rich Persian Gulf giants do, and this helps to explain why Saudi Arabia will likely continue to veto any marketing strategy that relies on a tightening of short-term production restraint by itself and its allies.

4.4.2 OPEC Market Manipulation Scenario

Following the crude oil price crash of 1986, there was a widespread suspicion amongst the non-OPEC oil industry that OPEC had initiated a new and cunning phase of oil market manipulation. OPEC's market share had been significantly eroded by increases in non-OPEC oil supply in the years leading up to the price crash. Between 1979 and 1985, non-OPEC supply increased by an average of more than 1 MMb/d per year, forcing the dramatic

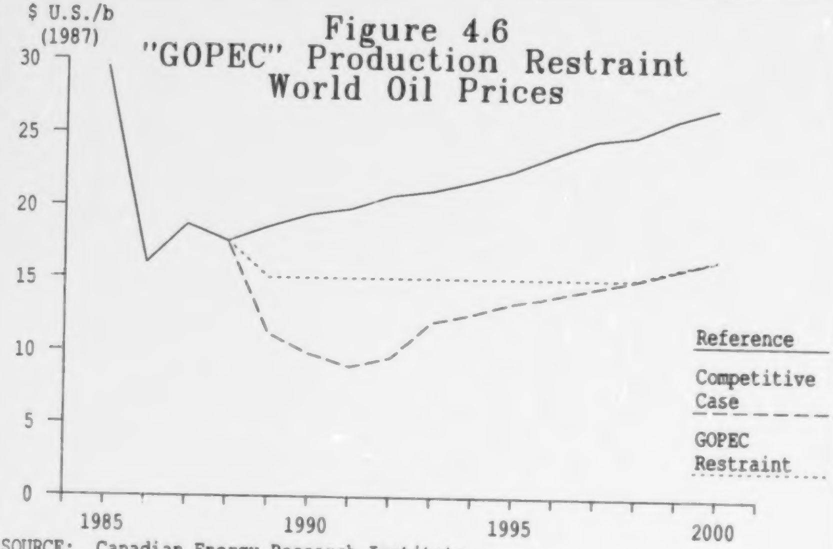


Figure 4.6
"GOPEC" Production Restraint
World Oil Prices

SOURCE: Canadian Energy Research Institute.

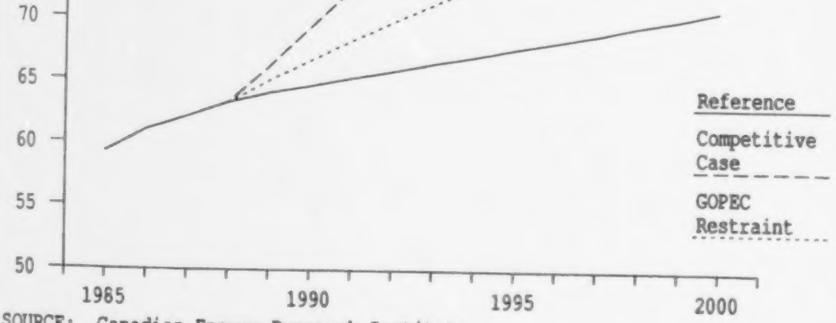


Figure 4.7
"GOPEC" Production Restraint
Market-Clearing Volumes

SOURCE: Canadian Energy Research Institute.

TABLE 4.13

"GOPEC" RESTRAINT SCENARIO PRODUCTION LEVELS 1988-2000 (MMb/d)

	Total OPEC		GOPEC	
Year	Competitive Market	GOPEC Restraint	Competitive Market	GOPEC Restraint
1988	18.8	18.8	7.6	7.6
1989	22.7	20.8	9.8	7.9
1990	26.2	22.2	11.6	7.6
1991	30.0	23.7	13.4	7.1
1992	32.5	25.5	15.0	8.0
1993	33.4	27.5	15.0	9.1
1994	34.4	29.3	15.8	10.7
1995	35.4	31.2	16.5	12.3
1996	36.4	33.1	17.3	14.0
1997	37.4	35.1	18.0	15.7
1998	38.4	37.1	18.8	17.5
1999	39.4	38.8	19.5	18.9
2000	40.4	40.3	20.3	20.3

SOURCE: Canadian Energy Research Institute.

TABLE 4.14

"GOPEC" RESTRAINT IN A COMPETITIVE MARKET: IMPLICATIONS FOR NET PRESENT REVENUE
1987-2000
(billions of $1987 U.S.)

Discount Rate	Total OPEC		GOPEC[a]		Saudi Arabia	
	Competitive	GOPEC Restraint	Competitive	GOPEC Restraint	Competitive	GOPEC Restraint
5%	1453.5	1530.3	668.2	613.4	432.8	380.2
10%	1026.7	1091.3	465.9	429.3	300.1	266.1
15%	762.6	816.8	341.7	316.7	218.8	196.3

SOURCE: Canadian Energy Research Institute.

[a] Includes Saudi Arabia, Kuwait, the United Arab Emirates and Qatar.

cutbacks in OPEC production that drove the cartel to the desperate measures of late 1985 and 1986.

Subsequently, in the face of OPEC's massive overproduction and plunging prices, some analysts came to the conclusion that the OPEC market share campaign was a deliberate attempt to drive competing suppliers out of business. With new non-OPEC development projects stalled and established fields depleting, OPEC would soon be in a position to move oil prices back up to the sky-high levels of the early 1980s. Before non-OPEC supply would have time to rebound, however, the cartel would drive prices back down for a relatively short period of time--just enough to scare investors away from the long-term commitments required for the development of alternative supply sources. This calculated OPEC "roller-coaster" would keep both consumers and non-OPEC suppliers off-guard. OPEC members could reap the benefits of high monopoly prices, with intervening periods of very low prices required to maintain the cartel's market position.

Recent events have made it clear that OPEC has not adopted anything resembling this calculated version of market manipulation. Statements by OPEC leaders stress their preference for a more stable pattern of world oil trade, with moderate prices and steadily increasing demand. Saudi Arabia, Kuwait, and the other Arab OPEC producers of the Persian Gulf have demonstrated that they are willing to actively block any efforts to push prices back above the $18 to $20 (U.S) per barrel range--as they did with their own overproduction in the summer of 1987 when prices reached $22 per barrel, and as they did again in April 1988 by scuttling a tentative pact with several non-OPEC suppliers that also would have sent prices soaring above $20 per barrel.

Moreover, there is considerable evidence that the deliberate market manipulation of the type described above would be impossible for OPEC to implement. It would require a tremendous degree of cohesion and internal unity within OPEC--this from an organization that has been consistently wracked by fundamental disagreements, open disputes, non-cooperation and even war between its members. The financial and political strains that such dramatic oil price cycles would place on OPEC members would be massive, and the risk of political, economic, and even military sanctions against OPEC by exasperated consuming nations could not be discounted.

Finally, it is increasingly clear that it would take extremely low prices to put any significant share of existing non-OPEC supply out of economic reach. Non-OPEC production has more than held its own since the price crash of 1986, increasing by almost 1 MMb/d over 1985 levels. Changes to government fiscal regimes and reductions in operating costs are continuing to ensure that non-OPEC supply remains viable, even in high-cost basins such as Canada's offshore East Coast region. Our analysis of global supply costs (see Figure 3.7) suggests that the vast majority of existing non-OPEC productive capacity is still economical to produce even at prices as low as $5 (U.S.) per barrel. To be sure, there would be a devastating collapse of new exploration and development activity resulting from very low oil prices, but this would not show up as a decrease in actual production volumes for some years afterward--greatly postponing OPEC's opportunity to increase prices and recoup the costs of the preceding price war.

Nevertheless, there are still some observers warning that OPEC has a hidden agenda: to restore the industrialized world's dependence on OPEC crude, and then to exploit that dependence with a series of dramatic oil price increases. With the CERI World Oil Market model, we can show that--even if it were possible to implement--this "roller-coaster" scenario of OPEC market manipulation would not even be in OPEC's best interest. Several different varieties of OPEC manipulation were simulated on the model. All involved very low prices for a certain period of time, followed by a period of high prices that lasted until OPEC's output shrank to a certain minimum level. Low prices were then re-instituted until it was "safe" for OPEC to restore the monopoly price. It was assumed in each scenario that OPEC's production quota system was precise and disciplined enough to maintain whatever oil price was desired.

Some key conclusions can be derived from these simulations. Most importantly, non-OPEC supply proved to be very insensitive to even massive decreases in price. For example, a sudden drop in real prices from $30 (U.S.) to $10 (U.S.) per barrel results in a decrease in total non-OPEC liquids supply of less than 2 MMb/d in the first year, and of less than 4 MMb/d over a 4-year period of consecutive $10 prices. This decrease in non-OPEC supply is much less than the decrease in world oil demand that results from relatively short periods of very high prices, with the result that OPEC's market share would shrink with each completed phase of the "roller-coaster" cycle. The rapid demand response to very high prices means that the monopoly peak to the pricing cycle could not be maintained for more than 2 or 3 years without reducing OPEC's total output to 15 MMb/d or less--levels which are clearly unsustainable, based on the 1985-1986 experience. On the other hand, it seems to take at least 4 years of very low prices for consumption trends to overcome the effects of previous high prices and create sufficient room in the market for OPEC production levels to recover.

From the numerous different versions of OPEC manipulation that were simulated, we have presented the results of the scenario that yielded the highest OPEC revenues on a present-value basis (see Figures 4.8 and 4.9,

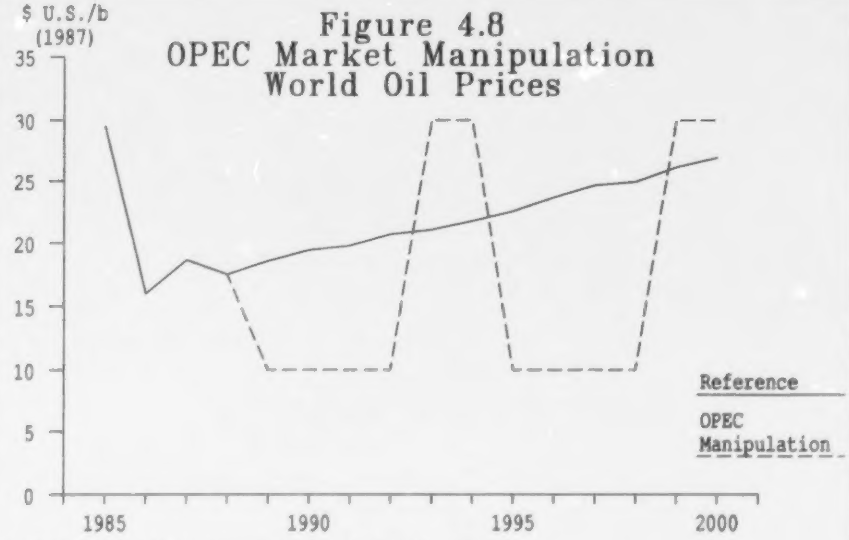


Figure 4.8
OPEC Market Manipulation
World Oil Prices

SOURCE: Canadian Energy Research Institute.

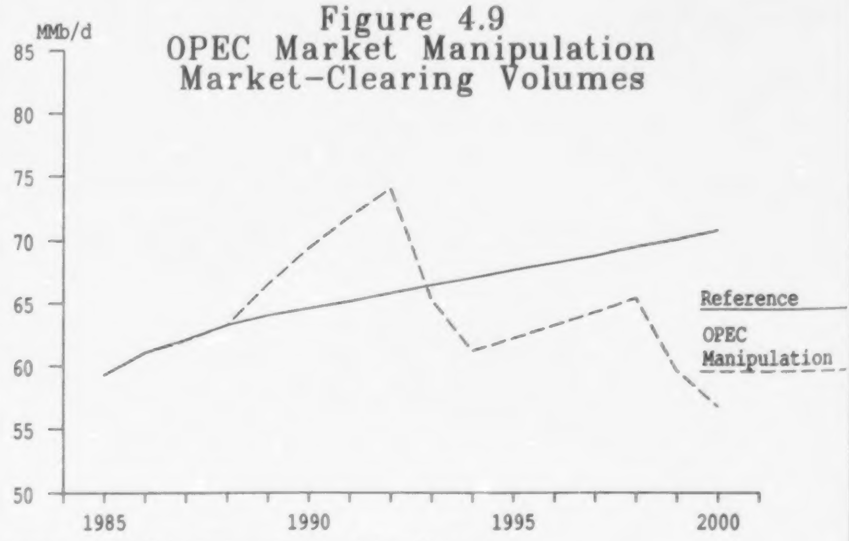


Figure 4.9
OPEC Market Manipulation
Market-Clearing Volumes

SOURCE: Canadian Energy Research Institute.

and Appendix F2). Four-year periods of very low prices ($10 U.S. per barrel in 1987 terms) are followed by 2-year periods of prices roughly equivalent to those that prevailed prior to the 1986 crude oil price crash. Non-OPEC liquids production is forecast to be relatively stable, never falling below 20 MMb/d over the forecast horizon. OPEC output, on the other hand, fluctuates widely due to variations in global consumption, falling to less than 15 MMb/d at the end of the second cycle of very high prices (see Table F2.2).

If OPEC's goal is to maximize its long-term crude oil revenues, then this "roller-coaster" strategy fares very badly in comparison to either the reference case or to the competitive market structure (see Table 4.15). In other words, OPEC as a whole would be better off to disband than to follow this tortuous path of cyclical market manipulation, since even relatively short periods of very high prices result in severe, demand-induced cutbacks to the cartel's market share. Clearly, the long-term interests of the major OPEC producers lie more with a stable and gradual increase in both oil prices and global oil consumption.

TABLE 4.15

COMPARISON OF PRESENT VALUE OF
OPEC CRUDE OIL PRODUCTION
1987-2000
(billions of $1987)

Discount Rate	Reference Case	Competitive Market	OPEC Market Manipulation
5%	1684.5	1453.4	1220.7
10%	1195.1	1026.7	897.7
15%	889.8	762.6	690.1

SOURCE: Canadian Energy Research Institute.

4.4.3 High Resource Scenario

Oil supplies outside of OPEC have proven to be surprisingly resilient in the face of falling real oil prices, relative to the general pessimism that surrounded non-OPEC supply projections during the 1970s. Estimates of the ultimately recoverable resources in the non-OPEC regions have either remained constant or been revised upwards over time. In Canada, for example, three studies have been released between 1975 and 1987 each estimating that some 3.7 billion barrels remain to be discovered in Western

Canada.[7] Similarly, in the U.S., Hubbert estimated in 1967 that 64 billion barrels remained to be discovered in the Lower-48 states.[8] This estimate remained essentially unchanged in the Geological Survey Circular 860 (released in 1981) except that the more recent study cites an additional 39 billion barrels remaining to be discovered in Alaska.[9]

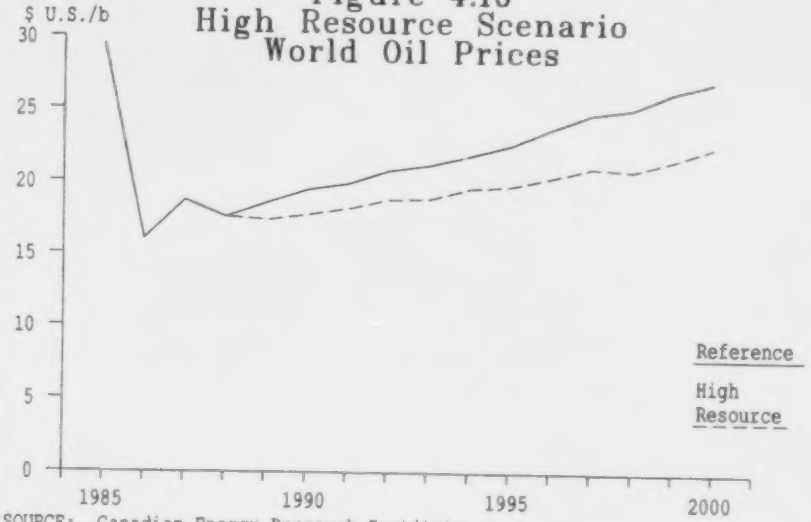
Estimates of recoverable world oil resources vary widely, depending on the assessor.[10] In Table 3.7, we provided a range of these estimates at three probabilities of occurrence for the non-OPEC countries. These estimates suggest that anywhere from 91.7 billion to 379.8 billion barrels remain to be discovered. Given that the LDCs countries have been explored far less intensively than North America and the North Sea, it is not unreasonable to suppose that the higher oil potential figures will eventually be realized. Indeed, in some instances, for example Egypt, the low estimate has already been surpassed by recent discoveries.

The structure of the World Oil Market model is such that the upside potential for crude oil resources in the non-OPEC countries can readily be examined (see Section 3.5.3). Essentially, the impact of assuming higher values for undiscovered resources is to push up projected finding rates in each region. As a result, given the same level of drilling activity, the time path of future discoveries will be greater, as will the projections of crude oil production.

This scenario examines the evolution of the world oil market under such an assumption. For comparative purposes, all other assumptions underlying the reference case, such as OPEC production levels, GDP growth rates and demand response parameters, are held constant.

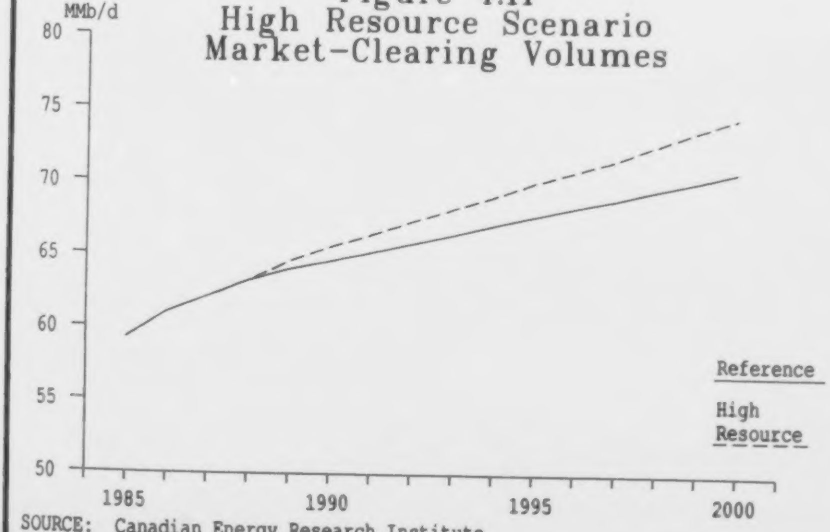
Figures 4.10 thru 4.12 summarize the essential features of the high resource scenario, comparing them with the reference case projections (Appendix F.3 contains detailed summary tables for this case). As illustrated in Figure 4.10, if assumptions regarding OPEC production levels are held constant, prices are significantly lower in the high resource case than in the reference case. Prices fall over 7 percent in 1988 to $16.83 per barrel before exhibiting a steady upward trend, increasing about 2.2 percent per annum over the remainder of the forecast horizon. By the year 2000, the oil price is projected to be $22.36 per barrel, some 20 percent lower than under the reference case. The gap between the two price tracks is fairly small initially, but widens over time before stabilizing in the last 3 years. In 1990, the price projected under the high resource scenario is $17.70 per barrel, 9.4 percent lower than under the reference case. By 1995 and 2000, the gap has widened to 14.3 and 20.3 percent, respectively.

Figure 4.10
High Resource Scenario
World Oil Prices



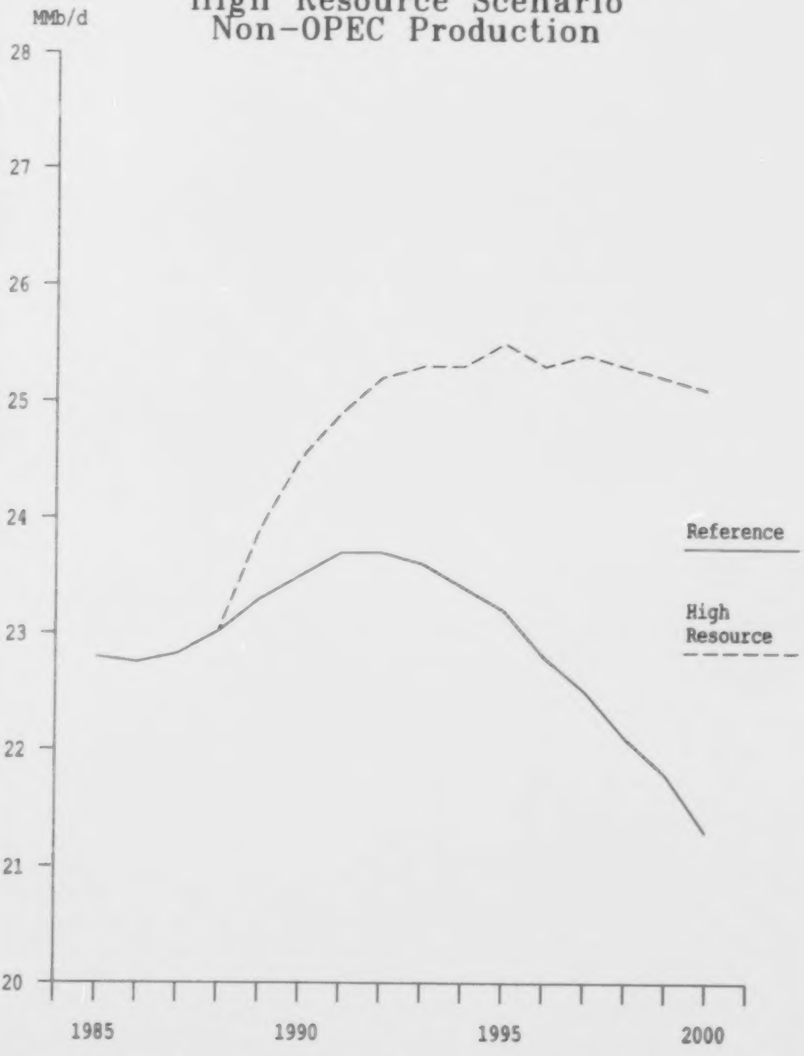
SOURCE: Canadian Energy Research Institute.

Figure 4.11
High Resource Scenario
Market-Clearing Volumes



SOURCE: Canadian Energy Research Institute.

Figure 4.12
High Resource Scenario
Non-OPEC Production



SOURCE: Canadian Energy Research Institute. Excludes NGL production and CPEs.

As in the reference case, the lagged effect of declining prices in recent years results in significant near-term demand increases. However, as shown in Figure 4.11, the lower prices under the high resource case provide an additional stimulus to demand growth. World demand growth is projected to average 2.1 percent in 1988, 1.6 percent in 1989 and 1.4 percent in 1990. Total world consumption increases from 62.3 MMb/d to 65.6 MMb/d over this period. After 1990, rising prices slow down the growth in world oil consumption. However, by the year 2000 world consumption is projected at 74.5 MMb/d, more than 3.7 MMb/d greater than under the reference case.

Lower prices and greater demand relative to the reference case are the product of greater non-OPEC crude oil production levels throughout the forecast horizon (see Figure 4.12). Although prices are lower in every year relative to the reference case, higher returns to drilling result in a peak production level of 25.5 MMb/d in 1995, compared to a peak of 23.7 MMb/d in 1992 under the reference case. These returns are also more sustainable and mitigate the decline in production relative to the reference case. By the year 2000, non-OPEC output falls only 400 Mb/d from its peak in 1995, to 25.1 MMb/d. Under the reference case, production levels are projected to drop over 2.4 MMb/d, to 21.3 MMb/d by the year 2000.

In our view, the high resource scenario provides a very legitimate alternative to the reference case scenario, in terms of the most-likely future path for crude oil prices. Given the extent to which non-OPEC production has increased between 1979 and 1985, OPEC is rightfully fearful of such a scenario unfolding. Although the cartel's production levels are the same as under the reference case, lower prices result in a 10 percent decline in annual revenues in 1990 relative to the reference case. This shortfall in revenue climbs to 20 percent by the year 2000. In present value terms, OPEC realizes about $1069 billion from the sale of its crude oil under this scenario (at a 10 percent rate of discount), some 12 percent less than under the reference case.

4.4.4 U.S. Import Fee Scenario

The anticipated decline in U.S. crude oil production has been referred to repeatedly in this study, specifically as the largest single source of decline in non-OPEC crude oil production over the forecast horizon. This decline in production is also cited as a critical factor underlying the projected upward trend in real crude oil prices under our reference scenario. While this may represent a panacea to the problems facing the OPEC nations, the cost and security implications of rising crude oil import requirements has been a topic of some concern and debate in the United States.

In March 1987, the U.S. Department of Energy released a comprehensive report on energy security in the United States.[11] The Department concluded that, under the base case assumptions for energy prices and economic growth employed in the study, U.S. net oil imports would be in the range of 8 to 10 MMb/d by the mid-1990s, representing some 50 percent of total U.S. crude oil consumption.[12] Such a degree of exposure to a highly uncertain and volatile world market raises potential economic and political security concerns.

The U.S. Department of Energy examined many possible options for reducing this world oil market exposure, such as continued off-oil conversion, adoption of switchable fuel technologies, and development of alternative renewable and nonrenewable energy sources. In addition, the study contained a detailed examination of the costs and benefits of an oil import fee or tariff, designed to both encourage indigenous crude oil supply development and to discourage growth in domestic crude oil demand. The study examined, among others, a fixed $22 per barrel price floor applied to all crude oil imports, and concluded that the potential economic costs of such a fee (through reduced international competitiveness, reduced GDP growth, economic dislocation and tariff administration) would outweigh the economic benefits accruing from decreased crude oil consumption, increased government revenue, and enhanced energy security.[13]

Later in 1987, the Energy and Environmental Policy Centre at Harvard University released a document challenging many of the conclusions reached by the U.S. Department of Energy regarding the oil import fee.[14] In particular, the study authors argued that the U.S. Department of Energy had significantly underestimated both the cost of rising U.S. oil imports and the benefits associated with an oil import fee. An import fee would not only reduce dependence on imported crude through reduced demand and enhanced production, but it would maintain downward pressure on world oil prices, encourage energy efficient and fuel flexible capital expenditures in the U.S., and offset the projected impact of growing crude oil imports on the U.S. trade bill.[15] The authors of the Harvard study concluded that a $10 per barrel import tariff on crude oil would be socially optimal but politically impossible, and recommended a $5 per barrel tariff as a minimum move in the right economic and energy policy direction.[16]

In November of 1987, the Canadian Energy Research Institute released a working paper which applied the Harvard tariff methodology to the Canada-U.S. free trade issue, assuming that Canada would be urged to adopt an import fee in response to similar actions by the U.S. government. The CERI analysis suggested that, given the difference in crude oil import exposure and terms of trade, an "optimal" oil import tariff for Canada would be in the order of \$3.60 (Cdn.) per barrel.[17]

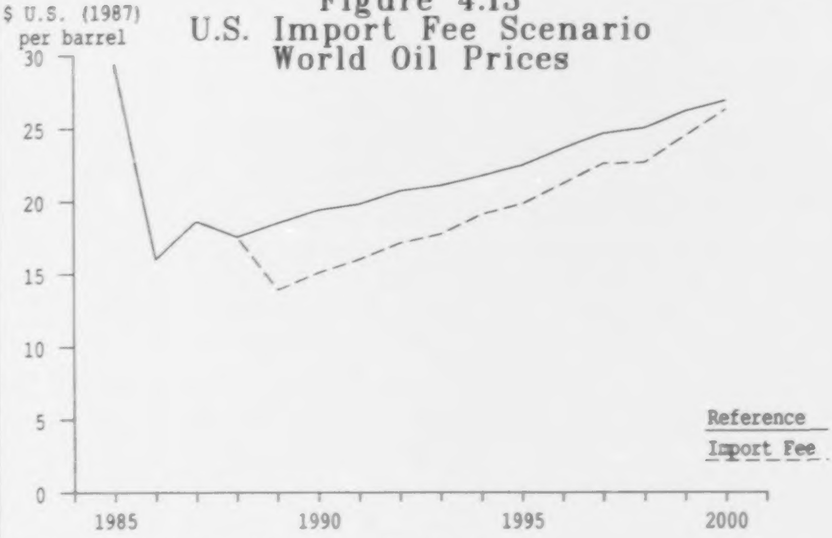
The CERI World Oil Market model provides an appropriate vehicle for analyzing the global impacts of a U.S. tariff on crude oil imports. In the analysis discussed below, we have set the domestic U.S. crude oil price at a floor of \$25 per barrel (\$1987 U.S.) effective in 1989; all crude oil produced domestically or imported into the U.S. is priced at a flat \$25 per barrel until the world price exceeds the floor price, at which point the U.S. domestic price is allowed to track upwards and the tariff falls to zero. The world price is determined using the same assumptions employed under the reference case discussed above.

The impact of imposing a U.S. import fee (or floor price) on the world oil price is shown in Figure 4.13. The reduction in U.S. domestic crude oil consumption and increase in U.S. oil production yields a fall in U.S. import requirements of over 1.0 MMb/d in 1989, rising to over 2.5 MMb/d in 1994 before falling to 1.2 MMb/d in 2000 due to GDP-related demand growth and declining U.S. production (see Figure 4.14). The differential in world oil price between the reference scenario and the U.S. import fee scenario peaks in 1990 at just under 29 percent, after which world demand growth in response to the price fall generates gradual real price increases over the remainder of the forecast period. By 2000, the world oil price is essentially equal under the two scenarios.

The impact on U.S. crude oil production and consumption, relative to the reference case, is shown in Figures 4.15 and 4.16, respectively. The primary impact on production is to reverse the decline in U.S. production volumes for two years, with a subsequent higher production track throughout the forecast period relative to the reference case.

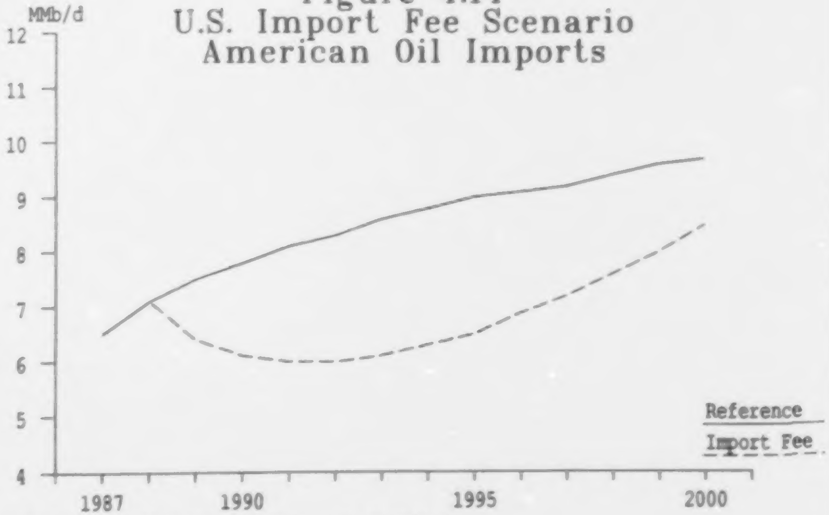
U.S. crude oil demand is sharply reduced in response to the oil price increase, falling over 760 Mb/d in 1989 relative to the reference case. The consumption differential between the two scenarios peaks at 1.6 Mb/d in 1993 before gradually declining to 860 Mb/d by 2000. This impact is likely understated, as conventional wisdom holds that the negative impact of such a tariff on U.S. GDP would offset the positive economic growth impacts associated with buoyant crude oil exploration and development activity. A greater negative impact on crude oil demand would lessen considerably the revenue gain accruing from the import fee. The current absence of an oil price-GDP feedback loop in the CERI World Oil Market model prevents us from capturing this effect on oil demand.

Figure 4.13
U.S. Import Fee Scenario
World Oil Prices



SOURCE: Canadian Energy Research Institute.

Figure 4.14
U.S. Import Fee Scenario
American Oil Imports



SOURCE: Canadian Energy Research Institute.

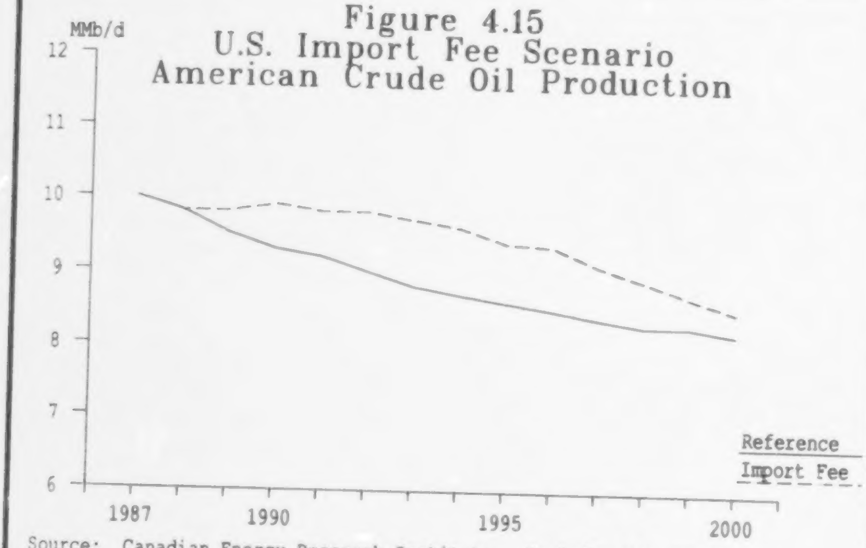


Figure 4.15
U.S. Import Fee Scenario
American Crude Oil Production

Source: Canadian Energy Research Institute. Includes NGL production.

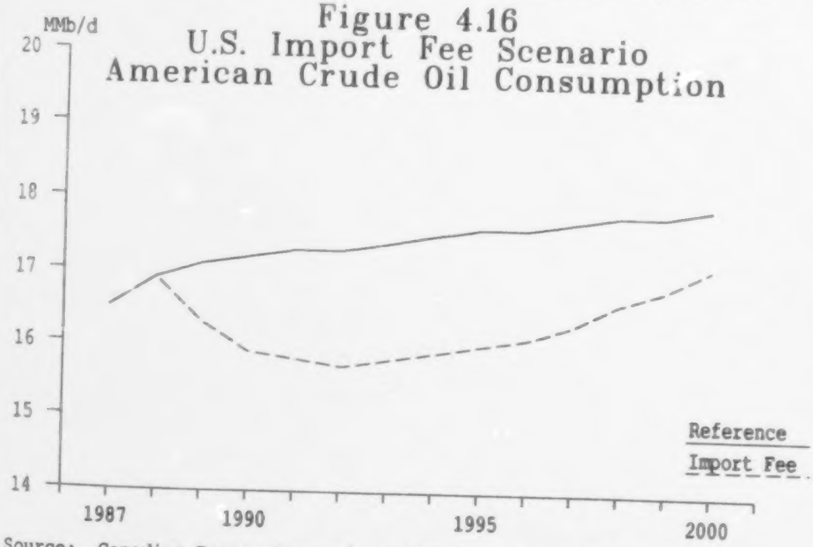


Figure 4.16
U.S. Import Fee Scenario
American Crude Oil Consumption

Source: Canadian Energy Research Institute. Includes NGL production.

The potential revenue accruing to the U.S. government from the import fee is shown in Figure 4.17. This is admittedly a rough estimate, representing the difference between the crude oil import price and the domestic floor price, multiplied by the annual import volume.[18] No account has been made for differences in import crude quality on delivered price, which would impact on the revenue margin received by the government.

The revenue take accruing to the U.S. government under this scenario is substantial. Given the impact of the import fee (through reduced demand for oil imports) on the world oil price, revenue from the fee peaks in the first year at $26 billion. The combination of gradually rising real crude oil prices, a continued decline in U.S. oil production, and an eventual GDP-induced recovery in U.S. crude oil import volumes, cause the revenue stream derived from the import fee to fall over time and decline to zero in 2000 as the world oil price recovers to a level above $25 (1987 $U.S.) per barrel. Indeed, the self-eliminating aspect of an oil price floor is one of the most seductive benefits of such a fiscal tool. Clearly, a lower floor price (say, of $20 per barrel) would have a similar economic impact but would be less disruptive and would be eliminated sooner.

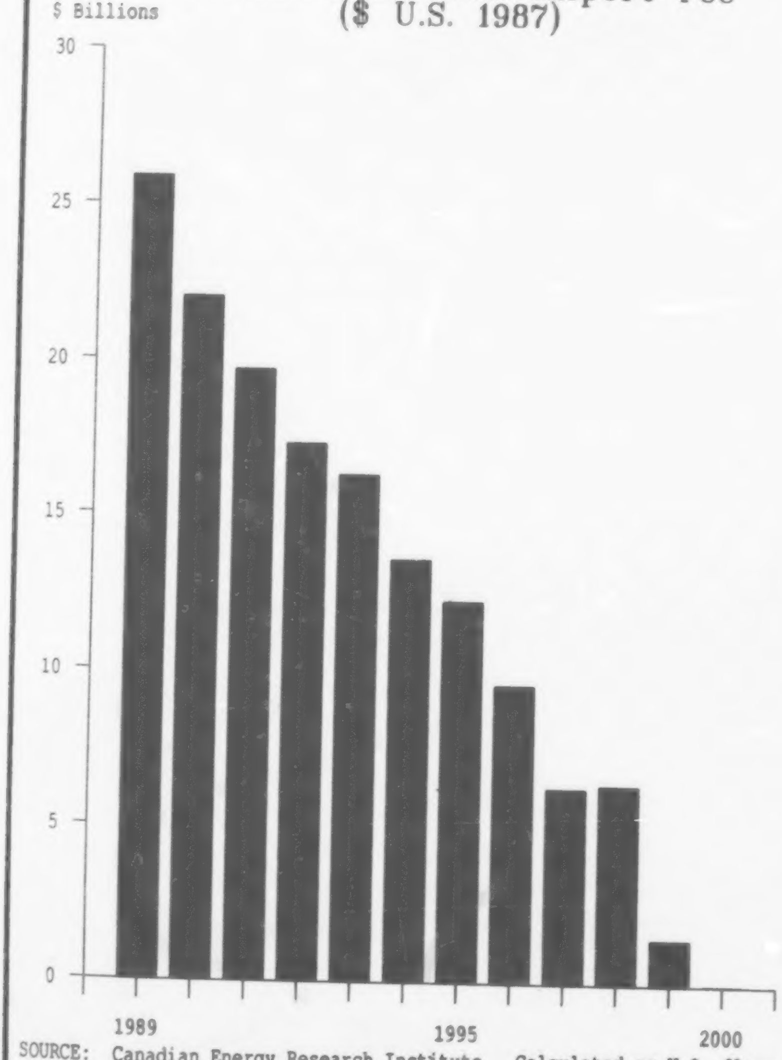
The total revenue take of the U.S. government under this scenario is roughly $410 billion ($1987 U.S., undiscounted). The potential benefits arising from this revenue take--an enhanced Strategic Petroleum Reserve, creation of a strategic reserve for refined petroleum products, amelioration of the equity impacts of the import fee, and/or paying down the U.S. debt--could be substantial. However, it remains unclear by how much (if at all) these benefits would outweigh the cost to U.S. industry of higher energy input costs.

4.4.5 Alternative Economic Growth Scenarios

As explained in Chapter 2, the demand side of the CERI World Oil Market model requires an exogenously-specified forecast of GDP growth in each of the seven different demand regions: Canada, the U.S., Western Europe, Japan and Australia, the less developed countries, the OPEC countries and the centrally planned economies. The reference case run of the model, together with the sensitivity scenarios described above, were run on the basis of 5-year GDP forecasts provided by Project LINK (see Appendix C). In this section, we will examine the sensitivity of projected oil prices to variations in this forecast of global economic performance.

The standard set of GDP forecasts used by the model is a rather conservative one, with real economic growth rates averaging about 3 percent per year in the developed market economies and slightly faster performance

Figure 4.17
Revenue From U.S. Import Fee
($ U.S. 1987)



SOURCE: Canadian Energy Research Institute. Calculated as U.S. floor price ($25/b) less world oil price, times import volume.

predicted for the Third World, OPEC and the centrally planned economies. Amongst the various views of future economic trends that differ from this prediction of moderate and stable growth, two scenarios are of particular interest to oil market analysts: the prospect for faster economic growth in the LDCs, and the risk of a serious recession in the OECD economies. Sensitivity runs of the CERI World Oil Market model were undertaken to examine the impact of these scenarios on oil prices, supply and demand.

Many economists believe that the United States and other OECD countries are due for an economic recession sooner or later--probably in 1989 or 1990. A moderate economic slowdown has already been incorporated into the Project LINK forecast which was used for the reference case projection described in Section 4.3--U.S. economic growth in the reference case scenario is projected to slow to 1.3 percent in 1989 and 1.6 percent in the following year. What would be the effect of a more severe recession on world oil markets? To answer this question, a sensitivity case of the CERI model was run with economic growth rates equal to zero for all OECD countries in 1989 and again in 1990. This would be a more serious downturn than the 1981-1982 recession, which helped to trim over 2 MMb/d from world oil demand. After 1990, projected economic growth returns to the standard rates utilized in the reference case.

The effects of the recession on world oil markets are surprisingly modest, as illustrated in Figures 4.18 and 4.19, and described in detail in Appendix 5. Thanks to the recession, oil prices average $19 (U.S.) per barrel (in real 1987 dollars) in 1990, as opposed to an estimated $19.40 in the reference case. The impact of the recession on oil consumption is also relatively insignificant, with world demand totalling some 64.5 MMb/d in 1990, less that 100,000 b/d lower than in the reference case. Even in the OECD countries themselves, oil consumption continues to grow despite the recession, by a total of some 300,00 b/d between 1988 and 1990. After the end of the recession, both world demand and oil prices recover to grow at rates similar to those of the reference case for the rest of the century.

Compared to the experience of the 1974-1975 and 1981-1982 recessions, therefore, we do not expect that an imminent economic downturn in the industrialized countries would have as dramatic an impact on oil markets. Relative to the 1970s, industry in Europe, North America and Japan is much less dependent on oil. A greater share of oil demand is thus composed of more "recession-proof" markets, such as the transportation and home-heating sectors. It should also be remembered that the two earlier economic crises were immediately preceded by huge oil price increases, which greatly amplified the effects of economic recession on oil consumption. If a

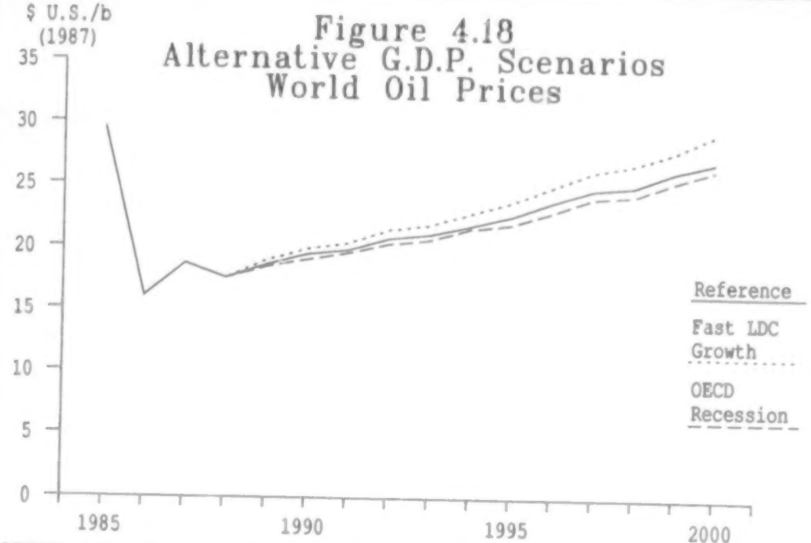


Figure 4.18
Alternative G.D.P. Scenarios
World Oil Prices

SOURCE: Canadian Energy Research Institute.

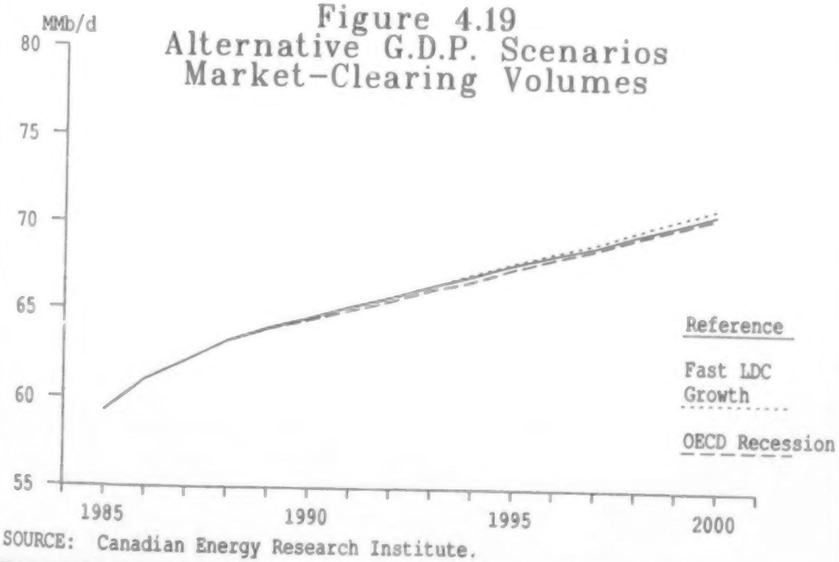


Figure 4.19
Alternative G.D.P. Scenarios
Market-Clearing Volumes

SOURCE: Canadian Energy Research Institute.

recession occurs in the next year or two, however, its impact on demand will be largely offset by the lagged effects of the recent large oil price decreases.

An upside to our reference case oil price forecast is provided by the possibility that economic growth in the LDCs will prove to be faster than we have specified. Growth in oil consumption in the developing countries has been faster and more consistent than in other regions over the last two decades. Unlike the OECD countries, LDC oil demand did not turn down following the twin oil price shocks of the 1970s, but rather continued to climb in tandem with economic expansion. OPEC and other oil producers are now counting on a continuation of this demand trend in the Third World to play an important role in firming up oil prices through the coming decade.

For the sensitivity analysis, we increased our forecast of LDC economic growth to an average 5.0 percent per year from the reference case projection of 3.5 percent per year. While certain Third World countries--including the rapidly industrializing economies of South Korea, Taiwan, Brazil and others--will experience economic growth well in excess of 5 percent per annum, this must be offset against the dire economic circumstance faced by many other countries in Africa, Asia and Latin America. Constrained by debt repayments and falling commodity prices, these economies have experienced economic stagnation or contraction that has pulled down average growth rates for the Third World as a whole. We consider it highly unlikely, therefore, that the LDCs would enjoy economic expansion that exceeded the five percent average rate postulated by this scenario.

Spurred on by a more rapid pace of economic growth, oil consumption in the LDCs grows at an average annual rate of 2.7 percent between 1987 and 2000 (compared to 1.9 percent in the reference case), and reaches 13.6 MMb/d by the end of the century (see Appendix F6 for details). The impact of this sustained expansion on oil prices is significant (see Figure 4.18); prices exceed $29 (U.S.) per barrel in real terms by the end of the century, compared to just under $27 per barrel in the reference case. So, oil market analysts are indeed correct in suggesting that demand growth in the LDCs could hold the key to a stronger recovery of oil markets in the next decade. Surprisingly, however, the net effect of faster LDC growth on aggregate world consumption is hardly noticeable. Oil consumption in the LDCs themselves is certainly higher, but this also produces the oil price increases described above, which in turn reduce oil demand in the highly price-sensitive OECD countries. Price fluctuations, therefore, work in such a way as to minimize the effects of varying economic growth scenarios on total world consumption (see Figure 4.19).

4.4.6 High CPE Net Export Scenario

An indirect but important influence in world oil trade is exercised by the centrally planned economies of the Soviet Union, Eastern Europe and China. Within these planned economies, the patterns of crude oil production and consumption are determined primarily by administrative fiat rather than by market forces. It is rather difficult to simulate this planning system from outside, so most world oil market models either ignore the CPEs altogether, or else incorporate them on the basis of certain important assumptions and simplifications. In the case of the CERI World Oil Market model, CPE oil consumption has been estimated purely on the basis of forecast GDP growth (see Chapter 2, footnote 5), while total CPE supply has simply been specified exogenously (see Section 3.4).

In one important respect, however, the problem posed by the CPEs can neither be ignored nor addressed by ad-hoc, wide-ranging assumptions. Net exports from the centrally planned economies are an important source of non-OPEC supply in the world oil market, and the level of these exports in the future could have a significant impact on world oil prices. An illustration of this importance of CPE net exports can be found in recent history. Since the crude oil price crash of 1986, net exports of crude oil and refined products from the centrally planned economies have increased by close to 500,000 b/d (see Table 4.16). Most of this increase has come from the Soviet Union, fueled by record-high production levels and a need for hard-currency export earnings. The increasing Soviet export flow has been one of the major barriers to OPEC's efforts to increase its own share of world oil trade. This has motivated a steady stream of OPEC diplomats to visit Moscow in an as-yet unsuccessful effort to seek the support of the Soviet Union for international cutbacks in world oil supply.

TABLE 4.16

CPE NET CRUDE AND PRODUCTS EXPORTS TO O.E.C.D
1984-1987
(Mb/d)

	1984	1985	1986	1987
U.S.S.R.	1,620	1,350	1,560	1,690
China	300	370	380	380
Other	290	280	330	370
Total	2,210	2,000	2,270	2,440

SOURCE: Petroleum Intelligence Weekly.

The reference case results described in Section 4.3 above were produced under the assumption that CPE net exports gradually fall to zero by the year 2000. This is not an unreasonable assumption, given recent trends in CPE supply and demand. If total CPE production is maintained at current levels (which would require a massive effort by the Soviet Union to replace its depleting reserves), and if CPE demand continues to grow slowly but steadily, then we expect that CPE net exports would be essentially eliminated as a source of non-OPEC supply by the end of this century.

But there is an equally strong argument to suggest that CPE net exports could follow a much more buoyant pattern in the coming decade. In the first place, there is considerable potential for increasing levels of production in both China and the Soviet Union. In China, some Western technicians have estimated that the development of major offshore and onshore discoveries could push output as high as 5 MMb/d by the year 2000. In the Soviet Union, remote fields in Western Siberia and the unexplored Arctic regions could similarly contribute to increases in total production, if and when they are developed. The dynamic reforms associated with "glasnost" and "perestroika" could also have a dramatic impact on the Soviet oil industry, both by promoting the more efficient use of domestic resources and by opening the doors to Western capital and technology.

Secondly, CPE net exports could also be boosted by demand-side measures, especially in the Soviet Union. Chinese oil consumption will almost certainly expand very rapidly in coming years, due to the massive

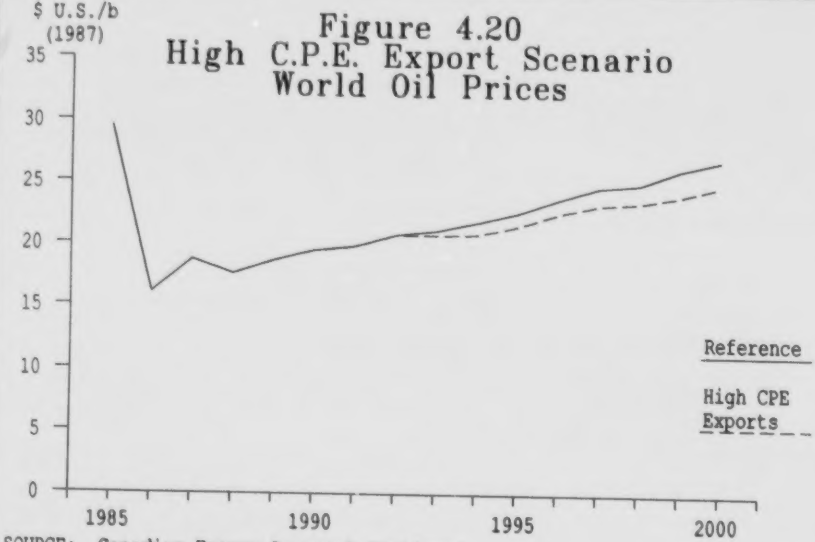


Figure 4.20
High C.P.E. Export Scenario
World Oil Prices

SOURCE: Canadian Energy Research Institute.

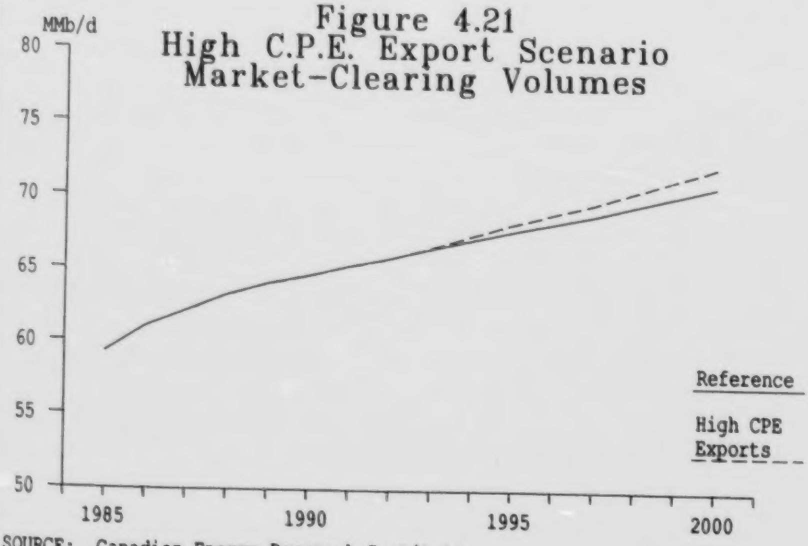


Figure 4.21
High C.P.E. Export Scenario
Market-Clearing Volumes

SOURCE: Canadian Energy Research Institute.

energy requirements associated with agricultural development, industrialization, and radical economic reform. Oil demand in China has grown at an average annual rate of almost 5 percent since 1982, and there is every indication that this trend will eat up most or all of the expected increase in Chinese oil supply, so that net exports will remain constant or decline. In the Soviet Union, however, there exists tremendous potential for oil conservation, as well as for the substitution of the country's enormous natural gas reserves for domestic oil consumption. "Glasnost" could affect oil markets on the demand side, as well, now that enterprises are evaluated on the basis of profitability, and are therefore forced to reduce costs (including energy costs) wherever possible. A continued need for hard-currency export earnings provides a strong incentive for the Soviet government to push ahead with oil conservation and substitution programs.

If production in the CPEs exceeds current projections, or if significant oil conservation measures are successfully implemented, the result will be an increase in the net exports supplied to world markets. To examine the impact that higher CPE net exports would have on world oil prices, we have run several sensitivity cases incorporating various assumptions regarding CPE production and consumption. The most plausible of these scenarios, presented here and in Appendix F7, assumes that Chinese net exports fall to zero over the next 5 years (due to rapidly increasing domestic demand), but that Soviet net exports are maintained at their current level of some 1.7 MMb/d until the end of the century.[19] As a result of this effective increase in non-OPEC supply, world oil prices are projected to be some $2 (U.S) per barrel lower by the year 2000 than in the reference case (see Figure 4.20). Thanks to the slower increases in oil prices, world oil consumption exceeds the levels projected in the reference case by over 1 MMb/d (see Figure 4.21).

It is clear, therefore, that the flow of CPE net exports will have a significant impact on the world oil market. We consider it virtually impossible that CPE net exports would be lower than specified in the reference case--it is not likely, in other words, that the centrally planned economies could become significant net oil importers by the end of this century. All of the uncertainty that clouds the future path of CPE net exports, therefore, is translated into downside price risk. If Soviet net exports are maintained at current levels, world oil prices will be some $2 (U.S.) per barrel lower than we have projected in the reference case. If Chinese oil exports are also maintained, or if CPE net exports were to actually increase (as they have since 1986), then the outlook for world oil prices would be even weaker.

Footnotes

[1] This is an estimate of the cartel's maximum sustainable capacity, as provided by the United States Directorate of Intelligence, International Energy Statistical Review (Washington, D.C.: August 1987), p. 2.

[2] See section 4.4.6 for a discussion of the rationale behind this assumption, and the implications of a more optimistic estimate of the future volume of CPE net exports.

[3] See, for example, M. A. Adelman, "The Competitive Floor to World Oil Prices," Energy Journal, October 1986; and Chris Hope and Phil Gaskell, "The Competitive Price of Oil," Energy Economics, October 1985.

[4] One estimate of OPEC productive capacity derived in this fashion is found in the U.S. Directorate of Intelligence review cited above. Other estimates of OPEC capacity have tried to take into account the erosion of capacity in recent years due to disuse and a lack of maintenance on shut-in production and transportation facilities. For example, Contingency Planning Associates has estimated short-term OPEC capacity at less that 28 MMb/d (Petroleum Intelligence Weekly, July 25, 1988).

[5] This assumes that an end to the conflict between Iran and Iraq allows both countries to develop production to historical peak levels. At time of writing, a U.N.-sponsored ceasefire between the Persian Gulf enemies seemed highly possible. During the last few years of conflict, both Iran and Iraq have produced at short-term, war-constrained capacity levels. For Iran, output has fluctuated between 1.5-2.5 MMb/d, and has generally fallen below its OPEC quota. For Iraq, which has repudiated its OPEC quota, output has grown steadily since 1983 and now exceeds 2.6 MMb/d. No shut-in, serviceable spare capacity exists in either country.

[6] It should also be noted that our competitive floor price of $9 (U.S.) per barrel is a yearly average price. Panic trading in the aftermath of OPEC's collapse would almost certainly send the price lower for short periods of time.

[7] Each study cited below considers only medium and light crude oil: Canada, Energy Mines and Resources, Oil and Natural Gas Resources of Canada 1976, Report EP 77-1 (Ottawa: Minister of Supply and Services, 1977); Canada, Geological Survey of Canada, Oil and Natural Gas Resources of Canada 1983, Paper 83-31 (Ottawa: Minister of Supply and Services, 1984); and Canada, Geological Survey of Canada, Conventional Oil Resources of Western Canada, Paper 87-26 (Ottawa: Minister of Supply and Services, 1988).

[8] This is Hubbert's optimistic estimate, contained in M. King Hubbert, "Petroleum Exploration in the United States", The American Association of Petroleum Geologists Bulletin, Vol. 51/11 (November 1967) p. 2226.

[9] These are the mean estimates contained in U.S. Department of the Interior, Geological Survey Circular 860, Estimates of Undiscovered

Recoverable Conventional Resources in the United States, (Washington, D.C.: 1981).

[10] See C. D. Masters, "Global Oil Assessments and the Search for Non-OPEC Oil" OPEC Review, Vol. XI, No. 2 (Summer, 1987), pp. 153-169, for a review of some of these different assessments.

[11] United States, Department of Energy, Energy Security (Washington, D.C.: Department of Energy, 1987).

[12] Ibid., p. 25.

[13] Ibid., pp. 72-74. See also Appendix D of the Energy Security study for details regarding the macroeconomic analysis performed by the U.S. Department of Energy.

[14] William W. Hogan and Bijan Mossavar-Rahmani, Energy Security Revisited (Cambridge, Mass: Harvard University, 1987).

[15] Ibid., p. 14.

[16] Ibid., p. 24.

[17] Morgan MacRae and Merete Heggelund, "Notes for Discussion on Aspects of Energy Security in Canada", paper presented to Energy Options seminar, Halifax, Nova Scotia, November 3, 1987, pp. 6-7.

[18] It is assumed here that the government would intervene in crude oil import purchases, effectively purchasing the crude from the foreign supplier at the prevailing world price and selling it to the domestic buyer at the higher domestic floor price. The calculations provided in section 4.4.4 do not account for quality differences relative to the WTI benchmark, but do give an indication of the order of magnitude of the revenue take. Presumably the revenue could be used to increase the Strategic Petroleum Reserve, develop a strategic refined petroleum product reserve, alleviate the negative effects of the tariff, and/or reduce the U.S. deficit.

It should be noted that a precedent of sorts does exist for this type of flat tariff, in the form of an import ceiling price established by the Canadian Government in the mid-1970s. In that case, the oil importer was compensated by the federal government for the difference between the controlled domestic price and the higher world oil price. The program was "financed" by Canadian oil export sales at the world price. The administrative costs of running this program would be a reasonable benchmark for assessing the costs of administering a U.S. import fee similar to the one discussed in this Chapter.

[19] In order to increase the level of Soviet net exports from the reference case, we chose to increase the exogenously-specified level of Soviet production. This does not mean, however, that we consider it more likely that Soviet exports would be boosted by way of increased output rather than decreased demand. The effect on world prices would be the same if we had changed the Soviet demand forecast and left the Soviet production schedule as it appeared in the reference case.

Chapter 5

SUMMARY AND IMPLICATIONS FOR THE CANADIAN ENERGY SECTOR

5.1 Stability Within Uncertainty

The preceding chapter, together with Appendices E and F, provide a detailed examination of the reference case and alternative scenarios selected for this initial report on CERI's research into the evolution of the world oil market. From these detailed results can be culled a number of general observations regarding the evolution of the world oil market.

The central finding of our research is that, despite the short-term volatility of the world oil market and the uncertainty inherent in a market structure dominated by a heterogeneous and fractious cartel, the market is fundamentally robust. Regardless of the severity of supply and demand side shocks placed on the market, the strength of the supply and demand fundamentals return the market to a stable, upward real price path. The artificial nature of the market-clearing (or equilibrium) price, resulting from the critical role of OPEC production in determining the level of the price, suggests that the market will not restabilize at a single price level after the impact of the shock has worked through the market. However, in all cases examined, including dissolution of the OPEC cartel, the world oil market returns to a stable, upward real price path. **Therefore, our key message to oil industry analysts, producers, consumers and policy makers is that the world oil market will respond to market uncertainties over the short-term, but follow a stable growth path over the long term.** This message is premised entirely on the strength of the fundamental supply and demand characteristics underlying the oil market. **Our second message, then, is that those involved in the oil market should focus their attention more on the fundamentals of the market, and less on the short-term fluctuations and volatility characteristic of the world oil market.**

Our third key message is that virtually all of the short-term price risk associated with the world oil market resides on the downside. Over the forecast horizon for this study, extending to the year 2000, the study authors were unable to develop a single plausible, rational market scenario that resulted in a crude oil price path above that of our reference case scenario. In this regard, the reference case scenario represents a "best-case" scenario for crude oil producers, and for the OPEC member nations. This resistance to significantly higher prices to the end of the century is based on strong, negative demand response to higher prices, and the ability of non-OPEC producers to increase productive capacity in response to higher prices. On this last point, we would reiterate that we ascribe an almost equal probability to the price path resulting from the High Resource Scenario (Section 4.4.3 and Appendix F3) as we do to the more optimistic price path associated with our reference case.

Following is a more detailed summary of the key results arising from our analysis of the world oil market.

5.1.1 Crude Oil Prices

The principal trend in crude oil prices under the reference case is of slowly rising prices through to the mid-1990s, followed by slightly accelerated price increases over the remaining years of the forecast horizon. Prices are projected to reach $22.50 per barrel by 1995 and $26.90 per barrel by the year 2000 (Note: all price and revenue figures are in constant, 1987 U.S. dollars). This trend is observed in all of the alternative scenarios; the severity of the market distortion in each case alters the rate of price increase, and in some cases extends the recent trend of declining oil prices for some time, but does not eliminate the eventual upward trend. Indeed, the return to an upward real crude price track under all scenarios underscores the robustness of the supply and demand fundamentals underlying the world oil market.

The alternative scenarios reveal the considerable downside risk associated with our reference case price path. The strength of non-OPEC crude oil production over the period 1982-1987, despite a gradual and then dramatic fall in real oil prices, has led the study authors to assign an almost equal probability to both the reference case and the High Resource Scenario (see Section 4.4.3). Under the latter, oil prices reach only about 22.50 per barrel by the end of the century.

The remaining scenarios are less likely to unfold, representing an assessment of particular issues or series of events which could impact on the world market. Of particular note is the Competitive Market Scenario (see Section 4.4.1) which analyses the possible collapse of OPEC and return to capacity production by the Persian Gulf producers. Two observations are worthy of note. First, the OPEC members with current surplus capacity "lose the least" under this scenario, being able to increase output to offset the dramatic fall in oil prices to $9.00 per barrel in the early 1990s. Indeed, only Saudi Arabia has the near-term capacity to actually benefit, in revenue terms, from the disintegration of the cartel. For the most part however, cartel members are clear losers under this low price scenario, which leads the study authors to conclude that OPEC will try to weather the current storm and reap the fruits of solidarity in the form of higher prices and output later in the 1990s.

Second, the price trough of roughly $9.00 per barrel is only slightly lower than that temporarily witnessed in the summer of 1986 and well above the marginal finding and production costs of the Middle East producers. While this is an annual average figure, and prices would be expected to fall below that level due to initial market over-reaction, the price trough is still well in excess of marginal costs of OPEC production.

The reasons for this are twofold. First, the fall in price generates a tremendous demand response, boosted by the lagged effects of the 1986-1987 price declines, which buffers the downward price pressure of increased supply and turns the market around by 1992-1993. Second, the scenario examined has OPEC production gradually returning to the previous peak capacity level of 33.4 MMb/d by 1993, allowing sufficient time for repair and reconstruction of abandoned and war-damaged production and transportation facilities.

If this return to productive capacity was achieved in a shorter time, the price would fall further. In this case, the demand response to the fall in price would offset a smaller share in of the massive increase in world supply.

5.1.2 Crude Oil Demand

A key result from our analysis is the important role of crude oil demand in tightening the world oil market, leading to real price increases through the 1990s. On an aggregate basis, gasoline demand shows the strongest growth over the projection period, averaging 1.6 percent growth per annum in the reference case versus zero growth for heavy fuel oil. This is due largely to the absence of alternative fuels to meet transportation requirements and the relatively heavy tax burden carried by motive fuels in most countries (which actually buffers motive fuel prices from changes in crude oil prices). HFO demand is constrained by the aggressive fashion in which all countries, and particularly those of the OECD, have pursued off-oil conversion and energy efficiency initiatives.

On a regional basis, crude oil demand growth is strongest in the LDCs and OPEC countries, averaging 2.0 and 2.5 percent per annum, respectively, under the reference case scenario. This reflects the rapid economic growth assumed for the LDCs and their heavy reliance on petroleum products to fuel that growth, and the continued subsidization of refined petroleum products in the OPEC countries. Oil demand in the OECD countries increases at a more modest 0.6 percent per annum, much of this predicated on burgeoning gasoline consumption in the United States. Of the forecast 8.0 MMb/d increase in world oil consumption between 1988 and 2000, only one-quarter is accounted for by the OECD countries.

In the alternative scenarios, rapid demand response to falling oil prices is conspicuous as the prime factor underlying the stability of the market. In the OECD countries, off-oil conversion initiatives and other capital-related oil reduction schemes have tended to leave the door open for temporary increases in petroleum product demand by maintaining dual-fired capability. Operational measures (lower thermostat settings, reduced lighting, reduced kilometres driven), which accounted for roughly one-half of energy productivity improvements in Canada over the past decade, are easily reversible and account for much of the short-term demand response.[1] In the other regions of the world, where crude oil is still the dominant energy source, low oil prices generate a significant demand response through both increased utilization and G.D.P. growth-induced demand.

5.1.3 Crude Oil Supply

In all cases excluding the Competitive Market and Market Manipulation scenarios, OPEC crude oil production is input exogenously and assumed to increase steadily from 18.8 MMb/d in 1988 to 27.4 MMb/d by the year 2000. Supply projections for all non-CPE, non-OPEC countries are developed within the CERI World Oil Market model. In the reference case, combined output in these countries is expected to increase from 23.2 MMb/d in 1988 to a peak of 23.7 MMb/d in 1992, and then decline to 21.3 MMb/d by the end of the century. Under the highly plausible High Resource Scenario, non-OPEC production peaks at 25.5 MMb/d in 1995, falling to only 25.1 MMb/d by the year 2000.

On a regional basis, the reference case results support the current consensus that future production gains will be located largely in the LDC countries. The North Sea, North America and Western Europe are all projected to experience production declines over the forecast period. Africa is expected to add some 1.2 MMb/d to regional production; Asia-Pacific, some 1.0 MMb/d; and South America a further 905 Mb/d. This result reinforces the decision of many major oil companies to move their risk capital out of the conventional reservoirs of North America and the North Sea and into the less familiar regions of Africa, Asia and South America. The greater potential for a major discovery outweighs the risk associated with existing or potential political and social instability. The discussion of resource potential in the producing countries, provided in Section 3.4, gives further support for this shift in exploration activity.

5.1.4 OPEC Market Strategy

The OPEC production scenario underlying the reference case reflects a market strategy of unified adherence to production quotas and a gradual increase in both production and market share (resulting from increased world demand and declining non-OPEC supply), accompanied by real price gains over the forecast horizon. In many respects, this represents a best-case scenario for the cartel. Production is increased by 8.6 MMb/d (or 46 percent) by the end of the century, generating a present value revenue stream of $1.2 trillion (under a 10 percent rate of discount). A collapse of the cartel, such as that described in the Competitive Market Scenario, would yield a present value revenue stream only 15 percent below that of the reference case. However, the costs of such a strategy are extremely uneven, and fall most heavily on those countries least able to afford them--the heavily populated, small resource base nations such as Nigeria, Algeria, and Indonesia. Alternatively, a market scenario that would see increased OPEC production restraint to support higher prices is also less favourable than the reference case--especially for the Persian Gulf nations which, under either a reserves- or production-based formula, would carry the lion's share of the cutbacks.

The possibility of OPEC collapsing down to a smaller, more unified cartel centered around the reserves-rich Persian Gulf states--a "GOPEC" scenario--has received considerable play in the western world and formed the basis for one of our alternative scenarios (see Section 4.4.1). Under this scenario, a four-nation mini-cartel--Saudi Arabia, Kuwait, the U.A.E. and Qatar--would restrain production to defend a world oil price of $15 per barrel. All other countries would be allowed to produce at capacity. From a revenue standpoint, adoption of such a GOPEC cartel is clearly counter-productive for the GOPEC members. These countries would actually gain more from a complete cartel collapse, and certainly do better under the reference case scenario.

Finally, for completeness, CERI analysts investigated a "roller coaster" price scenario in which OPEC would deliberately manipulate cartel production to produce large price spikes--both up and down--to scare investors away from the long-term commitments required for the development of nonconventional supply sources and--during the high-price spikes--to reap monopoly profits from oil consumers. This type of "roller coaster" scenario--with varying motives underlying the movement of prices--has gained a fair degree of credibility among companies in the less supply-secure

Western European countries. The CERI analysis concludes that, from a revenue standpoint, OPEC would be better off to disband than to follow this tortuous path of cyclical market manipulation. Again, it is the low half-cycle cost of current non-OPEC production combined with the rapid demand response to increases in the oil price that make this production market strategy nonviable for OPEC.

5.2 Planning in an Uncertain Environment: Messages for the Canadian Energy Sector

The key conclusions arising from our analysis of the world oil market are the following. **First, the long-term fundamentals underlying the world oil market imply strengthening crude oil prices through the 1990s.** In concert with the firming of crude prices will be a strengthening of the OPEC cartel, likely to be centered increasingly around the member countries in the Persian Gulf region. The gradual rise in crude oil price is predicated on steady growth in crude oil demand (particularly in the OPEC nations and the less developed countries), the inexorable decline in non-OPEC production (and U.S. production in particular), and a reasonable degree of cohesive market behavior on the part of the OPEC cartel.

Second, virtually all of the price risk associated with our reference price projection is on the downside. A lower than anticipated demand growth path--due to continued penetration of energy-efficient technologies into the capital base of the OECD countries and/or slower economic growth and/or revenue-constrained oil import purchases by the LDCs--appears to be the most likely source of consistent downward price pressure in the near term. It is highly unlikely that the oil supply-deficient economies of Japan, Western Europe and the United States will reverse their efforts toward oil conservation and substitution. This is particularly the case for the latter regions, where rapidly maturing natural gas distribution networks provide a ready alternative to refined petroleum products. Similarly, it is unlikely that those developing countries with proven or potential oil reserves will falter in their drive for increased domestic production, even in the face of low oil prices. Development of import-replacing domestic resources and industries remains one of the best sources of foreign currency for these developing economies.

On the supply side, the ability of the non-OPEC producing countries to prove up new reserves and maintain (or even expand) production volumes in the face of low prices continues to contradict the prognostications of industry experts. Our reference case is based on what we consider to be conservative estimates of ultimate potential reserves in the non-OPEC regions. Discoveries and reserves additions which exceed these conservative estimates will prolong the downward pressure on crude oil prices and extend the period before the OPEC members regain significant market share.

These key results--gradually strengthening real crude oil prices and the presence of considerable downside price risk--and the forces underlying this market scenario provide a number of important messages for the Canadian energy sector.

5.2.1 Canadian Energy Consumers

Canadians enjoy virtually unparalleled access to energy, both in terms of quantity of energy resources and choice among energy types. With the exception of the Atlantic region and the Territories (where crude oil products remain the primary source of fuel due to the lack of natural gas transportation infrastructure and, in the latter case, absence of a developed electric power grid), Canadian energy consumers can choose among plentiful supplies of oil, natural gas, coal and electricity to meet their energy requirements. Despite the artificially low crude oil prices of the 1970s, Canadian energy consumers have gone a long way in reducing their reliance on refined petroleum products, largely through energy conservation and energy efficiency measures. Refined petroleum product consumption as a share of total end-use energy consumption has declined from some 55 percent in the mid-1970s to 40 percent in 1987.[2]

Despite these impressive gains in off-oil energy consumption, certain regions and sectors in Canada are still critically affected by changes in crude oil prices. The Yukon and Northwest Territories and the Atlantic provinces remain heavily reliant on crude oil products and in the latter case, on crude oil imports. The transportation sector, particularly important to Canada with our small population spread across enormous distances, relies almost exclusively on crude oil products and will likely do so for the foreseeable future. Therefore, likely developments in the world oil market are of great importance to Canadian energy consumers, as are the messages to be gleaned from the likely evolution of that market.

The first message for energy consumers in Canada is that instability in crude oil prices, and hence in relative energy prices, is likely to be greater over the period to 1995 than later in the forecast horizon. Declining non-OPEC production, rising demand and gradually increasing OPEC production and market share should all serve to strengthen OPEC unity, and its grip on the world oil market, by the end of the 1990s. Therefore, it may be in the interest of energy consumers to invest in dual-fuel energy technologies in order to take advantage of relative price changes in the near and medium term.

Second, it appears that security of crude oil supply will be a minor concern over the next decade. This reflects the excess supply situation in the market and the ability of non-OPEC countries to maintain production levels, rather than the stability of OPEC. Short-term supply disruptions are adequately accommodated within the International Energy Agency emergency distribution agreement (of which Canada is a signator) and proper management of industry stockpiles.

Over the longer term, the importance of energy flexibility will likely decline as relative energy prices stabilize in response to renewed OPEC control over the world oil market. If available, energy consumers would be prudent in locking their energy requirements into long-term natural gas contracts, perhaps as early as the mid-1990s. It is highly likely that, beyond that point, crude oil price increases will exceed those of both the increasingly competitive natural gas market and the electricity market.

5.2.2 Canadian Oil Producers

Canada is a relatively small player on the world oil stage, accounting for under 3 percent of annual world production and possessing less than 1 percent of world proved oil reserves. However, the revenue, jobs, investment and economic growth generated by the roughly 500 million barrels per year of crude oil liquids production is important to the national economy, and of critical importance to the producing provinces of Western Canada and those affected by the emerging eastern and northern offshore basins.

Canada possesses established conventional crude oil reserves of 11.8 billion barrels, yielding a reserves life index in the order of 12 years. This is down considerably from the 30-year reserves life index for 1960, reflecting the inability of Canadian producers to replace production with new discoveries in the conventional areas. Canada also possesses tremendous reserves of nonconventional crude oil, located in the northern frontier, offshore of Atlantic Canada, and in the famous oil sands and bitumen deposits in Western Canada. Recent estimates suggest that some 1.7 trillion barrels of crude oil are contained in these bitumen deposits alone; however, it is estimated that only some 33 billion barrels are recoverable under current technology from surface mining operations, and another 33 billion from in situ operations (the latter yielding a very heavy crude that requires on-site upgrading or mixing with a diluent/light oil for transportation).[3]

Therefore, despite our enormous ultimate potential crude oil resources, Canada faces a strategic and growing shortage in light and medium crude oil. This shortage lies behind the ongoing discussions aimed at expanding our heavy oil upgrading capacity in Western Canada, and the recent decision by the federal and Newfoundland governments to financially support the accelerated development of the Hibernia oil field, located some 300 kilometres off the coast of Atlantic Canada. Serious discussions are currently underway concerning a similar acceleration of northern frontier development and the expansion of Canada's integrated mined oil sands capacity.

These projects are extremely sensitive to forecasts of crude oil prices. While government assistance can reduce the risk and uncertainty associated with nonconventional crude oil development, it takes considerable fortitude to commit a company's financial resources to a project which will produce crude oil at a supply price some five times the cost of incremental crude oil production in the Persian Gulf region. Corporate executives and energy advisors will be critically judged on their success (or failure) in accurately assessing the direction and magnitude of future changes in crude oil prices.

The principal message for energy producers arising from this study is to focus strategic and corporate planning initiatives firmly on market fundamentals. The machinations of OPEC over the next 2 to 3 years, and the exaggerated, speculative market response which will accompany them, will tempt corporate planners and senior executives to place undue emphasis on short-term developments in crude oil pricing. However, the analysis undertaken for this study shows the world oil market to be surprisingly robust, even in the face of significant supply and demand shocks. Exploration and development plans based on a projection of gradually rising real crude oil prices to the end of the century will serve corporate strategists well.

Second, planners should recognize the downside price risk exposed in our sensitivity analyses and incorporate this into their strategic planning exercises. As we have shown above, while it is possible for circumstances to arise which would drive the crude oil price to below $10 (U.S.) per barrel, it is highly unlikely that such low prices would be sustained for any length of time. Even a complete collapse of the cartel and the accompanying surge in production will only delay, not eliminate, the projected rise in real crude oil prices. Our analysis would suggest a downside project risk assessment based on $12 (U.S.) per barrel oil prices as adequate downside protection; highly risk averse companies may choose to lower this risk-adjusted hurdle price to the $10 per barrel level. However, it should be clearly recognized in project assessment exercises that these worst-case scenario prices are likely not sustainable over time.

Similarly, planners should recognize the much smaller likelihood of upside price potential relative to our base case. Numerous scenarios run by CERI analysts which attempted to force a higher price track for the market were largely unsuccessful. In each case, either negative demand response or positive non-OPEC supply response (or both) served to return the market to a lower price path. **The sequence of events which would be required to achieve a $25 (U.S.) per barrel oil price in 1990 (or even 1995) is largely inconsistent with market fundamentals.** It is true that this conclusion stops short of catastrophic events, such as an escalation in Mid-east tensions or an increase in active foreign military engagement in the Persian Gulf. However, it would be prudent for corporate planners not to base their decisions on such scenarios. In the context of a rational market evolution, there is little likelihood of significant upside price potential relative to our base case. Even if such events did develop, the resulting prices would not be sustainable for any extended period of time.

Our final message for producers concerns the development of megaprojects directed to the production of nonconventional reserves. While new technology and cost reductions will continue to improve the full-cycle economics of such projects, it appears that most of these projects carry supply prices near or above our reference price path for the mid-1990s. Government assistance, justified on the basis of regional development or employment objectives, may be forthcoming to improve the project economics. However, it is debatable whether or not this constitutes an appropriate expenditure of public funds. It may be more economic over the long-term to pursue enhanced production from existing producing regions and to focus attention on alternative sources of crude oil liquids or on alternative sources of transportation fuels, given that the latter is the only sector in Canada which is truly captive to world oil market developments.[4]

5.2.3 Canadian Energy Policy Makers

Energy policy in Canada over the last decade, and particularly policy pertaining to the crude oil sector, has been as volatile as the world oil market. From the highly interventionist federal policies of the late 1970s and early 1980s, with their myriad of pricing, taxation, incentive and support schemes, energy policy in Canada has come almost full circle with the deregulation and decontrol initiatives underlying the Western Accord, Atlantic Accord, and Canada Lands Act. Crude oil pricing, production, marketing and sourcing are all essentially deregulated, a scenario which is viewed favourably by Canada's energy producers as well as by large sectors of the general public.

The move to deregulation of Canada's oil industry has not meant the elimination of provincial and federal government involvement in the oil market. Various provincial royalty concessions and incentive programs are in place in Western Canada to assist in the continued development of Canada's conventional crude oil resource base, and to promote the expansion of nonconventional crude oil production. The federal government announced in July 1988 its intention to significantly underwrite the development of the Hibernia offshore oil reserves, through grants and loan guarantees to the project consortia. Similar actions may be forthcoming in relation to the development of the northern frontier resources, and the expansion of Canada's mined oil sands capacity.

These latter projects represent the upper fringe of world oil productive capacity development, costing billions of dollars to complete and yielding crude oil which will carry among the highest supply prices in the world. Many analysts are questioning the wisdom of such developments (and the fiscal responsibility of the federal government in lending its financial support) in the current climate of excess world oil supply and unstable, weak oil prices. The federal and provincial governments backing these projects are, in turn, pointing to the economic development spin-offs of these megaprojects and the likelihood of rising crude oil prices in the future, as support for their investment of public funds.

The first message to Canadian energy policy makers arising from this study is that, while adherence to long-term market fundamentals and appropriate downplaying of short-term market imbalances are essential for long-term policy planning, care must be taken to give sufficient weight to the risk associated with long-term price projections. For example, the implicit supply price for the Hibernia project (as understood from publicly available documents) is not out of line with our reference case price projection for 1995-1996, the estimated date of project completion. However, the risk associated with this projection lies almost entirely on the downside; it is feasible that crude oil prices could remain below the implicit Hibernia supply price (estimated by the authors) of $22-$24 ($1988 U.S.) per barrel through the end of the century.

This is not to suggest that public sector involvement in megaprojects is ill-advised. The economic development benefit of such large-scale projects may itself justify the public expenditure component of the development, regardless of the state of the project economics at the time of initial production. However, the magnitude of the public investment and the high degree of uncertainty surrounding the project economics certainly warrant the utmost caution.

The second message to Canadian energy policy makers concerns the upward track of real crude oil prices over the forecast period. While this is good news for the oil producing sector in Canada, it is tremendous news for the energy conservation and alternative energy interests in our country. **Major energy-saving gains remain to be made on the demand side of the oil equation, and alternative energies are positioned to take a greater share of the oil market in Canada.** The trigger to initiate (or re-establish) these activities is a higher crude oil price. Continued research, development and demonstration of these new technologies will lower their supply prices even further, and advance the timing of successful commercialization and application. **It is important that the public sector in Canada pay appropriate attention to these demands and supply measures, and not be overly swayed by the economic development benefits of large project developments.**

Finally, the current study provides implicit support for the current government stance on oil market decontrol and deregulation in Canada. The Canadian oil industry, unfettered by government intervention in the market-place, has proven its ability to withstand severe downward price pressures and to function in a highly volatile market situation. If the industry is similarly allowed to reap the rewards of gradually rising prices in the future, it is equally likely that it will thrive and continue to supply crude oil to Canadians well into the next century. **The future health of Canada's oil industry will once again test the strength of Canada's public sector support for market deregulation; Canadian energy producers and consumers should both hope that this support will remain strong.**

5.3 Areas of Further Research

As with any study of this magnitude, this report must be considered a first cut at the complex interrelationships underlying the world oil market. The Institute intends to further its research in this area by updating and refining the analytical framework underlying this study. In the fall of each year, CERI will release an update report to sponsors discussing the refinements made to the framework and analyzing various policy and market strategies which could impact on the evolution of the world oil market. The Institute encourages CERI sponsors and interested readers to forward their ideas for future analysis to the Institute to assist in making these updates as relevant and comprehensive as possible.

Following is a brief discussion of the refinements which CERI intends to make to the analytical framework over the next few years.

5.3.1 Third World Markets

The current analysis provides a fairly accurate representation of supply and demand characteristics of the oil markets of the developing countries. Established and ultimate potential reserves estimates, operating and capital costs, product demand profiles, and other aspects of these markets have been extracted from numerous sources and, where possible, validated by reference to producers operating in the various regions.

The growth of crude oil demand in the developing countries, and their ability to source these requirements from indigenous supplies, are critical elements in the evolution of the world oil market. If expected economic development in these countries is to be fuelled by crude oil purchased on the world market, one can anticipate a tightening of the market and an accompanying strengthening of crude oil prices. Alternatively, the ability of the developing countries to source their crude oil requirements internally will, to a large extent, determine the duration of the excess supply situation currently overshadowing the world oil market.

The Institute will be examining in greater detail the pattern of future reserves additions, productive capacity, and crude oil demand growth in the developing countries, beginning with an assessment of potential developments in Central and South America. Research will be undertaken in collaboration with industry and government officials experienced in the analysis of these particular oil markets.

5.3.2 Interfuel Substitution

The development of a more detailed representation of interfuel substitution (or "switchable" product demand) will be undertaken within the context of a more thorough investigation of the relationship between crude oil prices and end-use product prices. More specifically, future versions of the analytical framework will contain explicit feedback loops between crude oil prices and economic growth, and a preliminary representation of fiscal variables affecting the relationship between crude oil and product prices.

The primary focus of this analysis will be on the OECD countries, where technological penetration has enhanced the ability of industrial and commercial energy consumers, in particular, to react quickly to relative price changes among competing fuels. The switchable fuel market represents an increasingly important buffer against increases in real crude oil prices, particularly in North America and Europe where rapidly maturing natural gas distribution networks provide a ready competitor for escalating petroleum product prices. Initial research in this area will focus on Canada and the United States.

5.3.3 Centrally Planned Economies (CPEs)

The ability of the CPEs to maintain or increase net crude oil exports to the western world will have an important bearing on future crude oil prices. The need for foreign currency earnings to finance the economic restructuring of the Soviet bloc countries provides a tremendous incentive for maximizing crude oil exports. The success of the Soviet program to increase natural gas penetration (and off-oil conversions) within the Soviet economy, and the ability of the Soviet petroleum industry to prove and develop significant crude oil reserves in the increasingly harsh and remote areas pinpointed for future exploration activity, will ultimately determine the availability of CPE crude oil export volumes in the coming years.

The Institute will access industry experts on the Soviet economy in order to clarify the key policy, technical and geological considerations underlying future crude oil and natural gas developments in the CPEs. This information will then be incorporated within realistic scenarios of CPE net exports and their impact on the world crude oil market.

5.3.4 Reserves Additions and Production Costs

The marginal cost of operations in producing fields and the full-cycle cost of developing new reserves represent, in large part, the lower and upper bounds for crude oil price movements over the medium term. The current framework contains a sophisticated methodology for analyzing reserves additions, development and production within the non-OPEC producing countries.

An ongoing facet of Institute research will be to further refine the representation of drilling activity, finding rates, productive capacity and supply costs within the analytical framework. Industry and government sources around the world will be contacted to provide additional insights and to validate the data underlying the supply side of the modelling framework. It is critical to the analysis of future market strategies and price scenarios that the framework accurately represent half- and full-cycle production economics, in order to provide an accurate representation of non-OPEC supply response to potential future developments in the world oil market.

5.3.5 Uncertainty Analysis

Regardless of the accuracy with which one represents the current structure of the world oil market, it is impossible to fully predict the market response to potential supply and demand developments. Inaccuracy of established and ultimate potential reserves estimates, effects of technological improvements on finding and development costs, improved seismic and geological data analysis, lags in conservation and energy efficiency initiatives, irreversibility of energy efficient technologies, consumer expectations regarding future price developments, and a host of other tangible and intangible factors introduce a significant degree of uncertainty into the analysis of future developments in the world oil market. Analysis of alternative scenarios predicated on changes to key variables can provide a feel for the degree and impact of market uncertainty, but does not capture the linkages among the variables underlying future market development.

In designing the framework for analysis of the world oil market, CERI researchers accounted for uncertainty analysis by developing a framework conducive to the adoption of probability (or Monte Carlo-type) analysis of key variables underlying future market development. In the next round of research in this area, the existing model will be linked into an uncertainty analysis environment. By representing the analyst's perception of market uncertainty through the development of probability distributions around the most-likely value of key market variables, crude oil price projections will better reflect the degree of upside and downside risk accompanying these projections. In this way, users of the CERI world oil market reports will be better able to incorporate market uncertainty within their own planning and corporate strategies.

This report is the beginning of a body of research which the Institute believes will assist the Canadian energy sector in better understanding the forces underlying the evolution of the world oil market. The refinements anticipated for the analytical framework, combined with the increasing quality of oil market expertise housed within the Canadian Energy Research Institute, will make these annual reports on the world oil market an important and valuable contribution to the understanding of energy issues in Canada.

Footnotes

[1] Torrie, Smith and Associates, "Energy Security: The Demand Side Options," presented to the Energy Options seminar, Energy: The International Dimension, Halifax, Nova Scotia, November 4, 1988.

[2] Canadian Petroleum Association, CPA Statistical Handbook, Section VII, Table 4.

[3] International Energy Agency, Synthetic Liquid Fuels, (Paris: IEA, 1985), Table 2-3, and Canadian Petroleum Association, CPA Statistical Handbook, Table 10.

[4] For further information regarding the economics of nonconventional crude oil production and the current state of alternative sources of crude oil liquids, see CERI Study No. 27, An Assessment of the Potential for Coal-Derived Syncrudes in Canada (Canadian Energy Research Institute; June 1988) by Morgan MacRae.

For further information on alternative transportation fuels, see the forthcoming CERI study on the commercialization of ethanol and methanol in Canada, authored by Michelle Heath (October 1988).

APPENDIX A

PRODUCT DEMAND EQUATIONS

Appendix A

PRODUCT DEMAND EQUATIONS

The demand side of the CERI World Oil Market model specifies a total of 28 different refined product demand equations: one for each of four general product groupings (gasolines, middle distillates, heavy fuel oil, and other) in seven different demand regions (Canada, the U.S., Western Europe, Japan & Australasia, the LDCs, OPEC, and the centrally planned economies).

In each equation, product demand is a function of two exogenous variables: the price of the refined product, and a regionally disaggregated forecast of economic growth. To account for the lagged effects of previous changes in oil prices and national income, a third variable--previous changes in product demand--is also considered by the equation. The result is the autoregressive, Koyck-transformed constant-elasticity demand equation which has become widely accepted by demand analysts[1]:

$$D_t = a(P_t)^b(Y_t)^c(D_{t-1})^{1-d}$$

where:

D_t = product demand at time t

P_t = product price

Y_t = national income

D_{t-1} = lagged product demand

a = a constant

b = short-term price elasticity

c = short-term income elasticity

d = speed-of-adjustment parameter

A change in either price or GDP will affect product demand in the current year according to the short-term elasticities a and b . The cumulative effect of a change in either of the exogenous variables can be considered only by calculating the long-term price and income elasticities:

long-term elasticity = (short-term elasticity)/d

The speed-of-adjustment parameter, d , always falls between 0 and 1. The closer d is to 1, the faster is the adjustment of demand to changes in price and income, and the less important will be the lagged effects of previous changes in the exogenous variables.

As described in Section 2.4.3, the choice of values for the parameters of each demand equation--price elasticity, income elasticity, and speed-of-adjustment parameter--will have an important effect on the forecast levels of refined product demand. When we initiated the research for the demand side of the World Oil Market model, we consulted a wide range of econometric studies of refined product demand in various regions.[2] It became clear that there existed no widespread agreement as to either the precise form of a product demand equation that was appropriate, or the correct values of the respective price and income elasticities. The results of the various econometric analyses depended greatly on the specific demand equations that were estimated in each case.

There is no reason to believe that our own econometric estimates of refined product demand should be any more reliable than those of the dozens of econometric specialists who have also published their results. Rather than trying to replicate and improve upon this published work, we have instead chosen the most popular demand specification from amongst the various studies (the standard log-linear equation described above) and have selected elasticity estimates that are representative of the large sample of previous econometric work that we consulted. The flexibility of our modelling structure would then allow us to test for the effects of changes to our selected slate of product demand parameters.

The elasticity estimates that we used in the reference case runs of the World Oil Market model are detailed in Table A.1. Price elasticities are higher (in absolute terms) and speed-of-adjustment rates faster in the developed market economies, where it is assumed that a more sophisticated capital stock and flexible market structures allow for a faster and larger adjustment to changing relative energy prices. Income elasticities are higher in the developing countries, where the relationship between oil demand and economic growth is more direct. Price elasticities are larger (in absolute terms) for the heavier refined products--especially for heavy fuel oil--thanks to stronger competition from alternative fuels in the industrial and utility markets. Income elasticities are lower for these same products to reflect a long-term trend away from heavier products for environmental and other reasons.

TABLE A.1

PRODUCT DEMAND PARAMETERS

Region and Product	Short-Term Price Elasticity	Short-Term Income Elasticity	Speed-of-Adjustment Parameter
All OECD Countries			
Gasoline	-.1000	.1500	.2000
Middle Distillates	-.2250	.1000	.3000
Heavy Fuel Oil	-.3500	.0500	.4000
Other Products	-.1250	.1500	.2000
Less Developed Countries			
Gasoline	-.0975	.1500	.1500
Middle Distillates	-.1500	.2000	.2000
Heavy Fuel Oil	-.2000	.2500	.2500
Other Products	-.1000	.1000	.1500
OPEC			
Gasoline	-.0750	.1875	.1500
Middle Distillates	-.1200	.2500	.2000
Heavy Fuel Oil	-.1500	.3000	.2500
Other Products	-.0500	.1250	.1000
Centrally Planned Economies[a]:			
Gasoline	.0000	.3750	.7500
Middle Distillates	0000	.2812	.7500
Heavy Fuel Oil	.0000	.2812	.7500
Other Products	.0000	.3750	.7500

SOURCE: Canadian Energy Research Institute.

[a] In the Centrally Planned Economies, all price elasticities are set to zero, since consumption is determined by plan and not by market forces. The speed of adjustment factor is consequently higher for all products, as adjustment to changes in income are not a function of time lags to the same degree as are adjustments to price shocks.

The speed-of-adjustment parameter is very high for the centrally planned economies, since it is assumed that there is no direct relationship between world oil prices and CPE oil consumption. Economic growth, therefore, is the only determinant of oil demand in the CPEs. Economic expansion has a faster and more direct impact on oil demand than does a change in price, and it is, therefore, reasonable to expect that the lagged effect of previous changes in the exogenous variables will not have as significant an impact on product demand in the CPEs relative to the other demand regions.

Footnotes

[1] For an introduction to the Kocyck-transformed partial adjustment demand equation, see the description in G. S. Maddala, Econometrics (1977).

[2] See, for example, Carol A. Dahl, "Do Gasoline Demand Elasticities Vary?", Land Economics, 58 (3), August 1982; U.S. Department of Energy, Price Elasticity of Demand for Motor Gasoline and Other Petroleum Products, (Washington, D.C.: 1982); A. B. Askin and J. Kraft, eds., Econometric Dimensions of Energy Supply and Demand, (Lexington, Mass.: 1976); Energy Modeling Forum, Aggregate Elasticity of Demand (Stanford, Cal.: 1980); J. Kraft and M. Rodekohr, "Regional Demand for Gasoline: A Temporal Cross-Sectional Specification," Journal of Regional Science, 18 (1), January 1978; Robert Archibald and Robert Gillingham, "An Analysis of the Short-Run Consumer Demand for Gasoline," Review of Economics and Statistics, November 1980; C. Garbacz, "Residential Fuel Oil Demand," Applied Economics, August 1985; and N. D. Uri and S. Hassanein, "Gasoline and Fuel Oil Demand," Energy Economics, April 1985.

APPENDIX B

PRODUCT PRICE - CRUDE PRICE RELATIONSHIP

Appendix B

PRODUCT PRICE - CRUDE PRICE RELATIONSHIP

As described in detail in Appendix A, the refined product demand equations used by the CERI World Oil Market model utilize two exogenous variables: the price of the refined product in question, and a measure of regional economic growth. The supply/demand model as a whole, however, is designed to interact through a single world oil price, not a series of regional refined product prices. The model requires a mechanism, therefore, to convert the world crude oil price into the final end-use product prices that influence the level of refined product consumption.

The theoretical relationship between crude price and product prices was discussed in Section 2.3.1. Transportation costs, refining costs, distributors' margins, and taxes must be added to the price of crude oil feedstock in order to determine the price paid by the final consumer. If consistent data on each of these components of refined product prices could be gathered, and if those values could be exogenously forecast for future years, then the product price - crude price relationship could be explicitly modelled. In reality, however, a more approximate approach must be taken, since data on the various components of product prices is simply not detailed enough to allow for such precise calculations.

We have assumed that final product prices will depend on the world crude oil price in a straightforward linear fashion as follows:

$$\text{Product Price} = v + w\,(\text{Crude Price})$$

The constant v can loosely be interpreted as representing fixed processing costs, transportation, and taxes. The parameter w , on the other hand, reflects the variable costs of world oil feedstock, unstable distributors' margins, and value-added taxes.

Utilizing historical data on final refined product prices in various countries,[1] pooled cross-sectional time-series regressions were performed to derive rough estimates of these two parameters. These estimates are listed in Table B.1, together with the corresponding R^2 values resulting from the regressions.

TABLE B.1

PRODUCT PRICE - CRUDE PRICE PARAMETERS

Region and Product	Constant Factor (v)	Variable Factor (w)	R^2
Canada:			
Gasoline	15.00	2.00	.95
Middle Distillates	12.50	1.75	.90
Heavy Fuel Oil	2.75	1.25	.90
Other Products[a]	30.00	2.00	na
United States:			
Gasoline	15.00	1.50	.95
Middle Distillates	12.50	1.50	.90
Heavy Fuel Oil	2.75	0.80	.90
Other Products[a]	30.00	1.50	na
Western Europe:			
Gasoline	35.00	2.00	.95
Middle Distillates	20.00	1.75	.80
Heavy Fuel Oil	2.75	0.80	.95
Other Products[a]	50.00	2.00	na
Pacific OECD:			
Gasoline	25.00	2.00	.95
Middle Distillates	10.00	1.75	.95
Heavy Fuel Oil	3.25	0.90	.95
Other Products[a]	40.00	2.00	na
Less Developed Countries:			
Gasoline	20.00	1.80	.95
Middle Distillates	10.00	1.25	.95
Heavy Fuel Oil	3.25	0.70	.90
Other Products[a]	35.00	1.80	na
OPEC:			
Gasoline	7.50	0.50	.60
Middle Distillates	5.00	0.25	.30
Heavy Fuel Oil	2.25	0.25	.80
Other Products[a]	22.50	0.50	na
Centrally Planned Economies:[b]	na	na	na

SOURCE: Canadian Energy Research Institute.

[a] Regressions for the "other products" category could not be run due to a lack of product price data. These parameters were derived by using the same variable factor (w) as for gasoline, and the same constant factor (v) as gasoline plus a margin of 15.00, reflecting higher processing costs.

[b] In the Centrally Planned Economies, all price elasticities are set to zero, since consumption is determined by plan and not by market forces. There is no need to specify the parameters of the product price-crude price equations.

The primary weakness associated with this interpretation of the product price-crude price relationship is that it assumes that changes in crude oil prices are the only cause of changes in end-use product prices. Changes in government taxes or changes in refining and distributing margins could have an equally significant impact on final prices It is impossible, however, to forecast these changes in the non-oil components of refined product prices, so for a forecasting model of the world oil market the simplified approach that we have taken is the most feasible option.

Footnotes

[1] Obtained from the U.S. Department of Energy publication, International Energy Annual.

APPENDIX C

REFERENCE CASE G.D.P. FORECASTS

Appendix C

REFERENCE CASE G.D.P. FORECASTS

As described in Chapter 2, the CERI World Oil Market model requires as input data an exogenous forecast of economic growth in each of the seven major oil-consuming regions. The regional GDP forecasts used for the reference and test cases of the model are illustrated in Table C.1. Forecasts for the earlier years were taken from the long-run economic projections of Project LINK, a co-operative inter-governmental economic modelling project based at the University of Pennsylvania. Subsequent estimates were calculated by CERI analysts on the basis of long-term average growth rates. For a discussion of the effect on oil prices of changes to this reference case GDP forecast, please see Section 4.4.5.

TABLE C.1

FORECAST OF ECONOMIC GROWTH BY REGION
REFERENCE CASE
1987-2000
(% per year)

Year	Canada	U.S.A.	Western Europe	Pacific OECD	Less Developed Countries	OPEC	Centrally Planned Economies
1987	3.2	2.9	2.2	3.5	3.5	0.2	3.0
1988	2.2	2.4	1.8	3.2	3.5	1.4	3.1
1989	2.4	1.3	2.1	2.6	3.5	1.6	2.9
1990	2.9	1.6	2.3	3.2	3.5	2.8	3.2
1991	3.0	3.4	2.5	3.4	3.5	3.1	3.3
1992	2.6	2.6	2.5	3.5	3.5	3.6	3.4
1993	2.4	2.4	2.6	2.9	3.5	3.4	3.2
1994	2.1	2.1	2.5	2.1	3.5	3.4	3.7
1995	3.0	3.0	2.7	3.0	3.5	3.6	3.8
1996	3.3	3.3	2.9	2.3	3.5	3.5	3.9
1997	3.0	3.0	2.8	3.2	3.5	3.5	3.5
1998	3.0	3.0	2.8	3.2	3.5	3.5	3.5
1999	3.0	3.0	2.8	3.2	3.5	3.5	3.5
2000	3.0	3.0	2.8	3.2	3.5	3.5	3.5

SOURCE: Project LINK, Canadian Energy Research Institute.

APPENDIX D

ILLUSTRATION OF THE RESERVES ADDITIONS AND PRODUCTION SUBMODELS

Appendix D

ILLUSTRATION OF THE RESERVES ADDITIONS AND PRODUCTION SUBMODELS

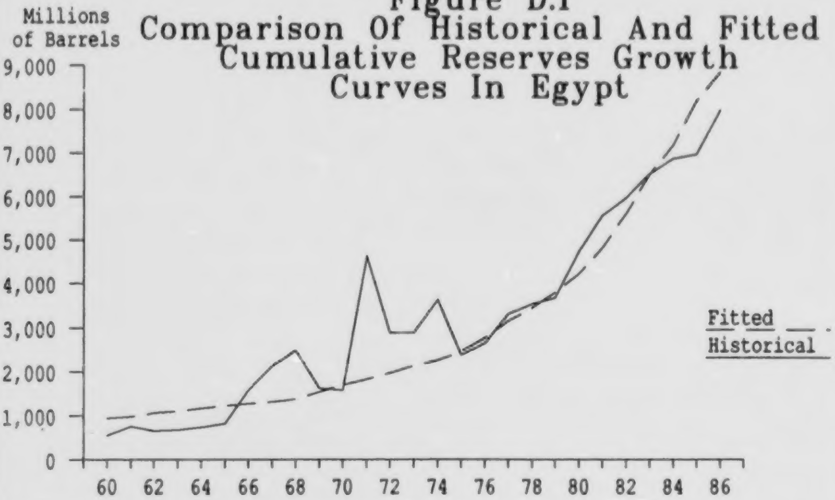
As discussed in Section 3.3.1.2, the Reserves Additions submodel fits cumulative growth curves to the estimates of ultimate recoverable crude oil resources for each non-OPEC country analyzed in this study. Figure D.1 shows the fitted cumulative growth curve for Egypt (provided as a case study for purposes of illustration) versus historical data. As shown in the figure, the cumulative growth curve provides a good approximation of actual reserves growth over the 1960-1986 period.

Figure D.2 shows the historical and estimated finding rates (expressed as barrels discovered per foot drilled) calculated by using the cumulative growth curve. Due to the uneven size distribution of pools in a given basin, and the high degree of risk associated with exploration activity, the estimated finding rate smooths considerably the actual historical experience in finding rates per year. To more accurately reflect the actual experience in crude oil discoveries would require an extremely detailed geological assessment of undiscovered pools in each reservoir or basin. Such data is not available on a global basis. Indeed, the pioneering work by the Geological Survey of Canada for the Western Sedimentary Basin in Canada (utilized in CERI Study No. 25, An Evaluation of Crude Oil Supply in Saskatchewan (1987) and a companion study of Alberta crude oil supply, (currently underway) represents one of the few attempts to model remaining undiscovered pools in a detailed, systematic manner.

Once the parameters describing the cumulative reserves growth curves have been determined for the given supply region, they are used to forecast future finding rates as a function of forecast drilling activity. The estimated finding rates in any year are then multiplied by that year's forecast drilling activity. The estimated finding rates in any year are then multiplied by that year's forecast drilling activity to yield an estimate of expected reserves additions.

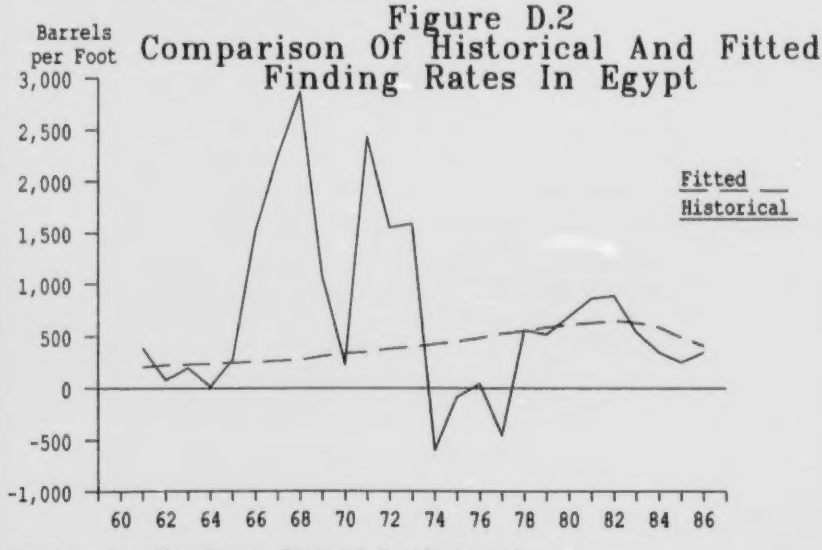
Figures D.3 and D.4 show projected finding rates and reserves additions for Egypt to the year 2000, for three possible levels of undiscovered crude oil resources, using the price scenario described in Section 3.4.1 (test case). The key observation to draw from these figures is that finding rates, and hence reserves additions, differ significantly depending on the level of

Figure D.1
Comparison Of Historical And Fitted Cumulative Reserves Growth Curves In Egypt



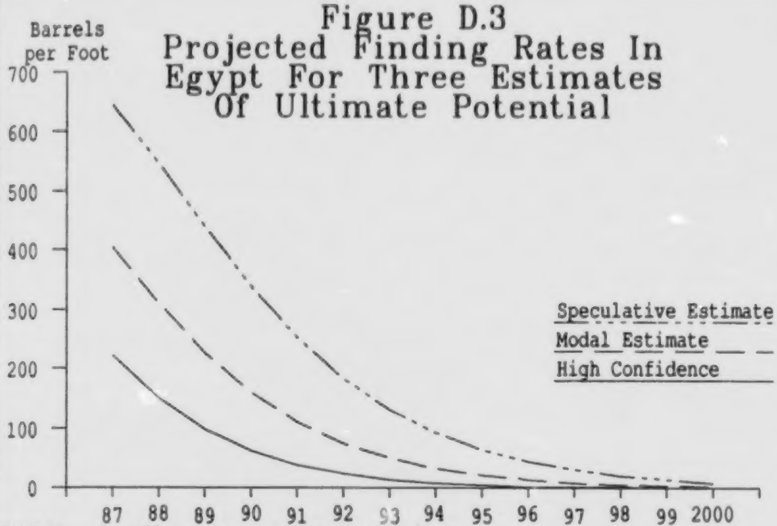
SOURCE: Canadian Energy Research Institute and World Oil Magazine, Various Issues.

Figure D.2
Comparison Of Historical And Fitted Finding Rates In Egypt



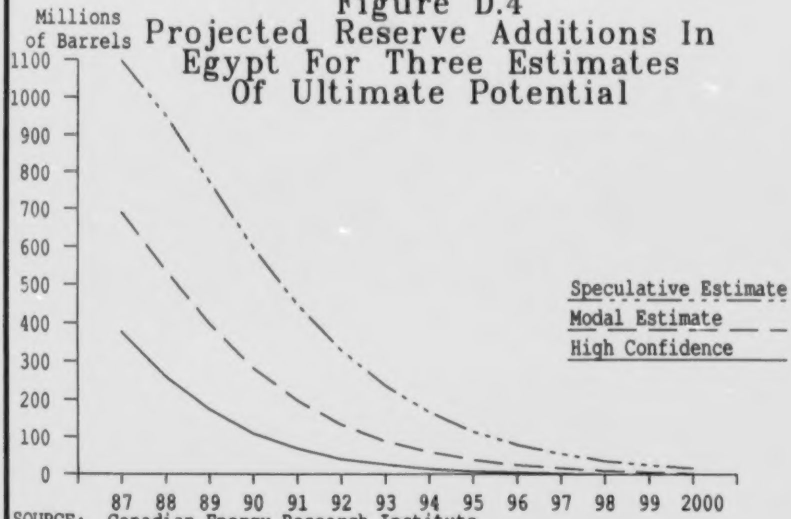
SOURCE: Canadian Energy Research Institute and World Oil Magazine, Various Issues.

Figure D.3
Projected Finding Rates In Egypt For Three Estimates Of Ultimate Potential



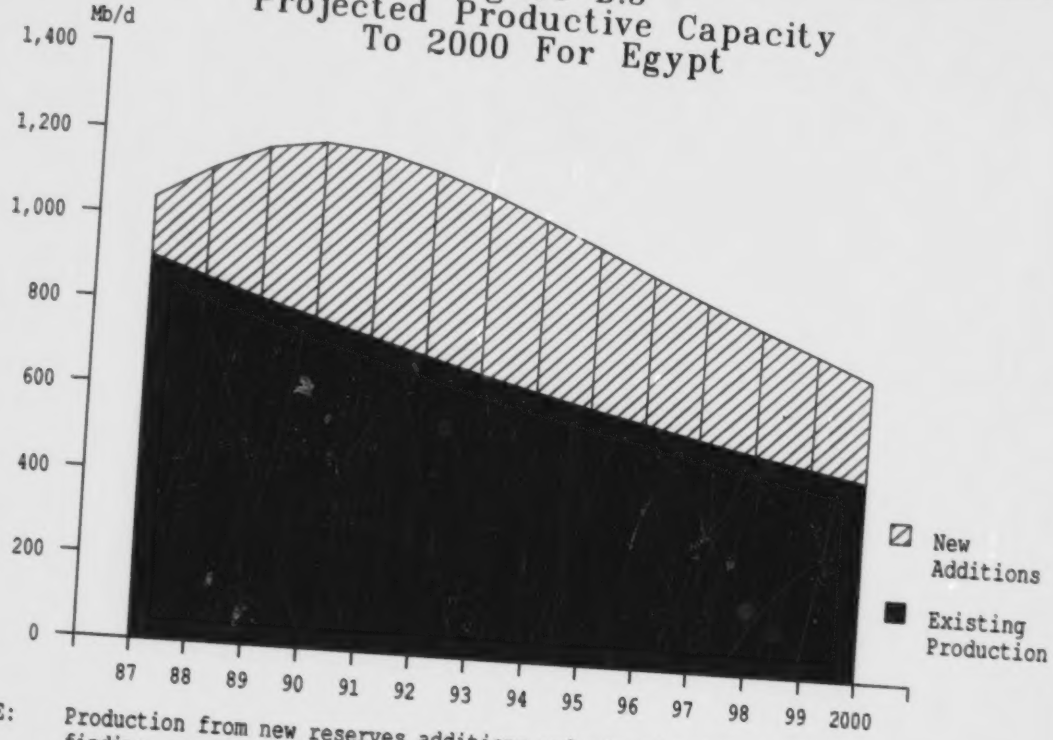
SOURCE: Canadian Energy Research Institute.

Figure D.4
Projected Reserve Additions In Egypt For Three Estimates Of Ultimate Potential



SOURCE: Canadian Energy Research Institute.

Figure D.5
Projected Productive Capacity
To 2000 For Egypt



NOTE: Production from new reserves additions calculated using finding rates established with the modal ultimate potential estimate.

SOURCE: Canadian Energy Research Institute.

undiscovered resources used to estimate the cumulative growth curve. Finding rates calculated using the speculative estimate (5 percent probability of occurrence) are 50 and 90 percent higher in 1987 than those calculated with the modal and high confidence (95 percent probability of occurrence) estimates, respectively. Finding rates under the speculative estimate also decline at a slower rate so that, by the year 2000, they are 100 and 200 percent greater than those estimated using the modal and high confidence estimates, respectively. This is an intuitively appealing result in that, if a region's resource potential is greater (or smaller) than expected, one would expect the time path of future discoveries to be affected in such a manner.

Finally, Figure D.5 provides a projection of productive capacity for Egypt from existing fields and from new discoveries, using the modal estimate finding rates shown in Figure D.3. Early in the time horizon, the decline in production from existing fields is offset by production from new discoveries, resulting in a 15 percent increase in total productive capacity by 1992. After this point, production from new discoveries can no longer offset the decline rate from pre-1987 existing fields, and total productive capacity declines through the end of the forecast period.

Clearly, the rate of development of, and production from, new discoveries is dependent on political and economic conditions in a given country, as well as on sound resource management practices. Therefore, a degree of flexibility was introduced by allowing the user to specify production profiles for future reserves additions in any region, based on specialized knowledge that might be available about the producing characteristics and conditions of that region. In all cases, the rate of production decline from existing fields is approximated by assuming that the decline rate is equal to the ratio of annual production to reserves, as would be the case under conditions of exponential decline.

APPENDIX E

DETAILED REFERENCE CASE RESULTS

E1 REGIONAL OIL PRODUCTS DEMAND

TABLE E.1

CANADA
REGIONAL OIL PRODUCTS DEMAND
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillate	Heavy Fuel Oil	Other	Total Crude Oil
1987	560	453	111	376	1,500
1988	560	448	111	385	1,505
1989	560	441	109	393	1,503
1990	561	434	106	401	1,503
1991	563	429	104	409	1,505
1992	565	424	102	417	1,507
1993	568	420	100	425	1,513
1994	571	416	98	433	1,517
1995	575	412	96	441	1,524
1996	579	407	93	449	1,529
1997	583	402	90	457	1,532
1998	588	399	88	466	1,541
1999	593	395	86	475	1,548
2000	599	391	84	484	1,559

SOURCE: Canadian Energy Research Institute.

TABLE E.2

UNITED STATES
REGIONAL OIL PRODUCTS DEMAND
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillate	Heavy Fuel Oil	Other	Total Crude Oil
1987	7,145	4,395	1,505	3,488	16,532
1988	7,292	4,475	1,594	3,516	16,878
1989	7,399	4,498	1,624	3,540	17,061
1990	7,482	4,490	1,622	3,563	17,156
1991	7,577	4,485	1,613	3,598	17,272
1992	7,662	4,462	1,589	3,636	17,349
1993	7,749	4,444	1,568	3,678	17,440
1994	7,826	4,417	1,541	3,720	17,504
1995	7,905	4,387	1,512	3,767	17,572
1996	7,981	4,345	1,475	3,819	17,620
1997	8,054	4,298	1,436	3,874	17,662
1998	8,142	4,270	1,410	3,935	17,757
1999	8,223	4,230	1,377	3,998	17,828
2000	8,309	4,195	1,348	4,064	17,916

SOURCE: Canadian Energy Research Institute.

TABLE E.3

WESTERN EUROPE
REGIONAL OIL PRODUCTS DEMAND
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillate	Heavy Fuel Oil	Other	Total Crude Oil
1987	2,657	4,916	2,415	2,211	12,198
1988	2,762	5,013	2,500	2,149	12,423
1989	2,850	5,053	2,512	2,100	12,516
1990	2,926	5,061	2,488	2,063	12,538
1991	2,996	5,064	2,461	2,039	12,560
1992	3,058	5,048	2,416	2,022	12,543
1993	3,118	5,037	2,380	2,014	12,549
1994	3,173	5,017	2,337	2,011	12,538
1995	3,225	4,992	2,291	2,012	12,520
1996	3,272	4,953	2,233	2,015	12,473
1997	3,316	4,907	2,172	2,020	12,416
1998	3,363	4,880	2,131	2,031	12,406
1999	3,406	4,840	2,079	2,042	12,368
2000	3,450	4,805	2,033	2,056	12,343

SOURCE: Canadian Energy Research Institute.

TABLE E.4

PACIFIC OECD
REGIONAL OIL PRODUCTS DEMAND
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillate	Heavy Fuel Oil	Other	Total Crude Oil
1987	975	1,574	846	1,671	5,066
1988	995	1,605	827	1,691	5,118
1989	1,012	1,615	803	1,711	5,141
1990	1,028	1,614	779	1,733	5,155
1991	1,045	1,613	761	1,759	5,178
1992	1,062	1,606	742	1,787	5,197
1993	1,079	1,601	728	1,817	5,225
1994	1,094	1,591	713	1,845	5,244
1995	1,109	1,579	698	1,875	5,261
1996	1,122	1,560	680	1,904	5,265
1997	1,135	1,540	662	1,935	5,271
1998	1,150	1,528	650	1,969	5,297
1999	1,164	1,512	635	2,004	5,315
2000	1,179	1,498	622	2,041	5,339

SOURCE: Canadian Energy Research Institute.

TABLE E.5

LESS DEVELOPED COUNTRIES
REGIONAL OIL PRODUCTS DEMAND
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillate	Heavy Fuel Oil	Other	Total Crude Oil
1987	1,662	3,450	2,222	2,293	9,628
1988	1,703	3,539	2,276	2,358	9,876
1989	1,742	3,616	2,316	2,417	10,091
1990	1,780	3,687	2,350	2,472	10,288
1991	1,820	3,762	2,388	2,526	10,497
1992	1,859	3,832	2,421	2,577	10,690
1993	1,901	3,909	2,460	2,628	10,897
1994	1,943	3,985	2,497	2,677	11,103
1995	1,986	4,060	2,533	2,724	11,304
1996	2,027	4,127	2,562	2,768	11,484
1997	2,067	4,190	2,588	2,810	11,655
1998	2,111	4,265	2,625	2,854	11,855
1999	2,154	4,334	2,656	2,895	12,038
2000	2,198	4,407	2,690	2,936	12,231

SOURCE: Canadian Energy Research Institute.

TABLE E.6

OPEC
REGIONAL OIL PRODUCTS DEMAND
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillate	Heavy Fuel Oil	Other	Total Crude Oil
1987	840	1,503	794	606	3,744
1988	855	1,532	807	622	3,816
1989	869	1,557	816	637	3,879
1990	884	1,584	826	653	3,947
1991	901	1,617	840	670	4,028
1992	920	1,654	856	688	4,118
1993	942	1,697	875	707	4,221
1994	966	1,743	895	727	4,331
1995	992	1,793	917	748	4,450
1996	1,019	1,844	939	770	4,572
1997	1,047	1,897	961	793	4,699
1998	1,078	1,956	987	818	4,838
1999	1,110	2,015	1,012	844	4,981
2000	1,144	2,078	1,039	871	5,132

SOURCE: Canadian Energy Research Institute.

TABLE E.7

CENTRALLY PLANNED ECONOMIES
REGIONAL OIL PRODUCTS DEMAND
1987-2000
(Mb/d)

Year	Gasoline	Middle Distillate	Heavy Fuel Oil	Other	Total Crude Oil
1987	2,554	3,925	3,924	3,052	13,455
1988	2,595	3,974	3,973	3,102	13,644
1989	2,632	4,017	4,016	3,147	13,811
1990	2,674	4,065	4,064	3,198	14,002
1991	2,717	4,114	4,113	3,250	14,193
1992	2,762	4,165	4,164	3,304	14,394
1993	2,807	4,216	4,215	3,358	14,595
1994	2,857	4,273	4,272	3,418	14,820
1995	2,912	4,335	4,334	3,484	15,065
1996	2,967	4,397	4,396	3,550	15,311
1997	3,020	4,456	4,455	3,613	15,544
1998	3,074	4,515	4,514	3,677	15,780
1999	3,129	4,575	4,574	3,743	16,021
2000	3,184	4,635	4,634	3,808	16,260

SOURCE: Canadian Energy Research Institute.

E2 DETAILED REGIONAL SUPPLY FORECAST

TABLE E.8

ANGOLA/CONGO/CAMEROON
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	776.3	329	255.7	650.1	0.0	650.1
1988	747.3	308	230.4	659.0	0.0	659.0
1989	773.9	286	221.3	667.1	0.0	667.1
1990	795.8	262	208.8	674.6	0.0	674.6
1991	806.7	238	192.1	679.6	0.0	679.6
1992	828.9	214	177.1	682.0	0.0	682.0
1993	838.3	190	158.9	681.6	0.0	681.6
1994	856.8	166	142.3	678.4	0.0	678.4
1995	875.7	144	126.0	672.6	0.0	672.6
1996	904.4	123	111.4	664.3	0.0	664.3
1997	931.0	104	97.0	653.8	0.0	653.8
1998	938.5	87	82.0	641.0	0.0	641.0
1999	968.3	73	70.4	627.0	0.0	627.0
2000	987.3	60	59.3	612.1	0.0	612.1

SOURCE: Canadian Energy Research Institute.

TABLE E.9

ARGENTINA
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	3,721.8	29	109.1	413.7	31.3	445.0
1988	3,578.3	28	101.1	401.4	31.6	433.0
1989	3,820.3	27	104.1	398.3	31.9	430.3
1990	4,047.4	26	105.8	396.7	32.3	428.9
1991	4,174.5	25	104.3	396.6	32.6	429.2
1992	4,412.0	24	105.0	398.1	32.9	431.0
1993	4,537.4	23	102.4	399.3	33.2	432.5
1994	4,745.0	21	101.1	400.8	33.6	434.4
1995	4,959.5	20	99.4	401.9	33.9	435.8
1996	5,264.6	19	98.7	403.0	34.2	437.3
1997	5,548.8	17	96.7	403.9	34.6	438.5
1998	5,660.7	16	91.2	404.2	34.9	439.1
1999	5,978.7	15	88.6	404.1	35.3	439.4
2000	6,197.1	14	84.0	402.9	35.6	438.5

SOURCE: Canadian Energy Research Institute.

TABLE E.10

AUSTRALIA/NEW ZEALAND
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	1,537.7	97	149.1	551.9	92.9	644.8
1988	1,450.7	94	136.4	542.2	93.8	636.0
1989	1,530.4	91	139.1	533.5	94.8	628.3
1990	1,596.2	88	139.8	525.4	95.7	621.1
1991	1,628.8	84	136.9	517.3	96.7	614.0
1992	1,695.4	80	136.3	509.6	97.7	607.2
1993	1,723.9	77	132.0	501.6	98.6	600.3
1994	1,779.2	73	129.3	493.7	99.6	593.3
1995	1,836.1	69	126.0	485.6	100.6	586.2
1996	1,922.3	64	123.9	477.7	101.6	579.3
1997	2,002.0	60	120.4	469.7	102.6	572.3
1998	2,024.8	56	113.0	460.9	103.7	564.6
1999	2,114.2	52	108.9	452.0	104.7	556.7
2000	2,171.1	47	102.5	442.5	105.8	548.3

SOURCE: Canadian Energy Research Institute.

TABLE E.11

BRAZIL
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	4,368.5	128	559.4	607.5	20.8	628.3
1988	4,320.8	120	517.8	645.9	21.6	667.5
1989	4,364.4	109	475.6	681.7	22.5	704.2
1990	4,400.6	96	423.9	713.7	23.4	737.1
1991	4,418.4	83	366.9	737.1	24.3	761.4
1992	4,454.9	70	312.0	751.8	25.3	777.1
1993	4,470.5	58	258.9	758.1	26.3	784.5
1994	4,500.8	47	212.1	756.9	27.4	784.2
1995	4,532.0	38	171.4	749.1	28.5	777.5
1996	4,579.3	30	137.4	735.9	29.6	765.5
1997	4,623.0	24	108.9	718.3	30.8	749.1
1998	4,635.5	18	84.9	697.3	32.0	729.3
1999	4,684.5	14	66.4	675.3	33.3	708.6
2000	4,715.7	11	51.3	652.8	34.6	687.4

SOURCE: Canadian Energy Research Institute.

TABLE E.12

CANADA
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	26,842.5	13	356.5	1,518.5	353.5	1,872.0
1988	25,797.9	13	324.0	1,482.0	357.0	1,839.1
1989	26,873.4	12	316.6	1,458.5	360.6	1,819.1
1990	27,768.7	11	304.4	1,432.9	364.2	1,797.1
1991	28,221.7	10	285.4	1,404.0	367.9	1,771.9
1992	29,128.2	9	269.2	1,372.4	371.5	1,744.0
1993	29,528.6	8	247.1	1,381.3	375.2	1,756.5
1994	30,294.4	7	227.2	1,375.8	379.0	1,754.8
1995	31,080.8	7	206.7	1,369.4	382.8	1,752.2
1996	32,257.5	6	188.1	1,343.8	386.6	1,730.5
1997	33,346.4	5	168.5	1,332.1	390.5	1,722.6
1998	33,682.5	4	146.2	1,297.0	394.4	1,691.4
1999	34,903.9	4	129.0	1,311.9	398.3	1,710.3
2000	35,699.4	3	111.4	1,293.4	402.3	1,695.7

SOURCE: Canadian Energy Research Institute.

TABLE E.13

COLUMBIA AND OTHER SOUTH AMERICA DETAILED REGIONAL SUPPLY FORECAST 1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	2,897.8	103	297.9	426.4	0.0	426.4
1988	2,845.8	95	270.0	463.2	0.0	463.2
1989	2,893.4	87	251.4	495.7	0.0	495.7
1990	2,932.8	79	231.1	523.5	0.0	523.5
1991	2,952.2	71	209.1	544.8	0.0	544.8
1992	2,992.0	63	188.9	560.0	0.0	560.0
1993	3,009.0	56	168.0	569.1	0.0	569.1
1994	3,042.0	49	149.2	572.9	0.0	572.9
1995	3,076.0	43	131.7	571.7	0.0	571.7
1996	3,127.5	37	116.1	567.7	0.0	567.7
1997	3,175.1	32	101.6	559.6	0.0	559.6
1998	3,188.7	27	87.3	547.7	0.0	547.7
1999	3,242.1	23	75.8	532.5	0.0	532.5
2000	3,276.1	20	64.9	514.4	0.0	514.4

SOURCE: Canadian Energy Research Institute.

TABLE E.14

EGYPT/TUNISIA
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	1,710.2	405	693.4	996.6	30.6	1,027.2
1988	1,750.7	310	542.3	1,073.2	31.2	1,104.5
1989	1,766.9	226	399.1	1,132.7	31.8	1,164.6
1990	1,781.8	159	283.9	1,152.4	32.5	1,184.9
1991	1,790.6	110	196.4	1,140.8	33.1	1,173.9
1992	1,804.7	74	133.9	1,108.3	33.8	1,142.1
1993	1,812.2	50	89.8	1,062.6	34.5	1,097.1
1994	1,824.2	33	59.8	1,009.7	35.2	1,004.9
1995	1,836.6	22	39.5	953.6	35.9	989.4
1996	1,854.1	14	26.1	896.9	36.6	933.4
1997	1,870.7	9	17.1	841.3	37.3	878.6
1998	1,877.8	6	11.1	787.8	38.0	825.9
1999	1,896.5	4	7.2	737.0	38.8	775.8
2000	1,909.9	2	4.6	689.1	39.6	728.7

SOURCE: Canadian Energy Research Institute.

TABLE E.15

MEXICO
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	2,208.8	1,184	2,614.4	2,584.3	336.6	2,920.9
1988	2,106.2	1,186	2,498.1	2,661.4	343.3	3,004.8
1989	2,200.1	1,183	2,603.3	2,742.3	350.2	3,092.5
1990	2,277.8	1,175	2,676.2	2,825.4	357.2	3,182.6
1991	2,316.2	1,161	2,688.3	2,907.6	364.3	3,271.9
1992	2,394.8	1,141	2,731.5	2,990.4	371.6	3,362.0
1993	2,428.4	1,114	2,706.1	3,070.5	379.1	3,449.6
1994	2,493.6	1,083	2,699.7	3,148.9	386.6	3,535.5
1995	2,650.7	1,045	2,676.9	3,224.7	394.4	3,619.1
1996	2,662.3	1,003	2,700.0	3,298.8	402.3	3,701.1
1997	2,756.3	955	2,632.5	3,369.8	410.3	3,780.1
1998	2,783.2	903	2,512.6	3,433.6	418.5	3,852.1
1999	2,888.6	848	2,449.7	3,493.2	426.9	3,920.1
2000	2,955.8	790	2,335.8	3,546.1	435.4	3,981.5

SOURCE: Canadian Energy Research Institute.

TABLE E.16

MALAYSIA/BRUNEI
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	1,144.2	280	320.4	684.9	46.0	730.9
1988	1,132.8	272	308.3	689.7	46.0	735.7
1989	1,143.3	263	300.8	717.4	46.0	763.4
1990	1,151.9	252	290.8	745.0	46.0	791.0
1991	1,156.2	241	278.5	772.5	46.0	818.5
1992	1,165.0	228	266.2	799.5	46.0	845.5
1993	1,168.7	215	251.8	821.9	46.0	867.9
1994	1,176.0	202	237.6	840.6	46.0	886.6
1995	1,183.5	188	223.0	854.6	46.0	900.6
1996	1,194.8	175	210.0	864.8	46.0	910.8
1997	1,205.2	161	194.6	871.2	46.0	917.2
1998	1,208.2	148	179.3	873.7	46.0	919.7
1999	1,220.0	136	165.7	872.8	46.0	918.8
2000	1,227.5	124	151.9	868.0	46.0	914.0

SOURCE: Canadian Energy Research Institute.

TABLE E.17

NORTH SEA
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	2,540.5	365	926.2	3,420.4	244.8	3,665.2
1988	2,449.1	328	803.0	3,486.9	249.7	3,736.6
1989	2,532.8	289	731.3	3,545.0	254.7	3,799.7
1990	2,602.0	248	646.4	3,591.7	259.8	3,851.5
1991	2,636.2	209	550.6	3,654.2	265.0	3,919.2
1992	2,706.2	171	464.1	3,700.0	270.3	3,970.3
1993	2,736.1	138	377.5	3,608.8	275.7	3,884.5
1994	2,794.2	109	304.7	3,507.2	281.2	3,788.4
1995	2,854.0	85	242.5	3,396.2	286.8	3,683.1
1996	2,944.6	65	192.4	3,238.8	292.6	3,531.4
1997	3,028.3	50	150.7	3,077.6	298.4	3,376.0
1998	3,052.2	38	115.3	2,915.5	304.4	3,219.8
1999	3,146.2	29	89.8	2,752.7	310.5	3,063.2
2000	3,206.0	21	68.9	2,592.3	316.7	2,909.0

SOURCE: Canadian Energy Research Institute.

TABLE E.18

OTHER AFRICA
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	349.0	542	189.3	32.3	0.0	32.3
1988	343.5	535	183.6	34.0	0.0	34.0
1989	348.5	527	183.6	35.6	0.0	35.6
1990	352.7	519	183.0	37.2	0.0	37.2
1991	354.8	511	181.1	38.8	0.0	38.8
1992	359.0	502	180.3	40.4	0.0	40.4
1993	360.8	494	178.1	42.0	0.0	42.0
1994	364.3	485	176.7	43.5	0.0	43.5
1995	367.9	476	175.2	45.1	0.0	45.1
1996	373.4	467	174.4	46.6	0.0	46.6
1997	378.4	458	173.3	48.1	0.0	48.1
1998	379.9	449	170.4	49.6	0.0	49.6
1999	385.5	439	169.3	51.0	0.0	51.0
2000	389.1	429	167.1	52.4	0.0	52.4

SOURCE: Canadian Energy Research Institute.

TABLE E.19

OTHER MIDDLE EAST
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	2,138.3	370	791.1	871.7	42.8	914.6
1988	2,087.7	332	694.0	977.5	43.7	1,021.2
1989	2,134.0	297	633.6	1,167.8	44.6	1,212.4
1990	2,172.3	262	570.1	1,303.3	45.5	1,348.7
1991	2,191.2	230	503.7	1,411.2	46.4	1,457.5
1992	2,229.9	200	445.6	1,485.4	47.3	1,532.7
1993	2,246.5	172	387.0	1,523.6	48.2	1,571.9
1994	2,278.6	148	336.3	1,538.7	49.2	1,587.9
1995	2,311.7	126	290.5	1,529.9	50.2	1,580.1
1996	2,361.7	106	251.1	1,500.8	51.2	1,552.0
1997	2,408.0	89	215.0	1,458.1	52.2	1,510.3
1998	2,421.3	75	180.5	1,403.3	53.3	1,456.6
1999	2,473.2	62	153.3	1,342.6	54.3	1,396.9
2000	2,506.3	51	128.5	1,278.8	55.4	1,334.2

SOURCE: Canadian Energy Research Institute.

TABLE E.20

PAKISTAN/INDIA
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	3,581.0	126	450.0	755.6	6.0	761.6
1988	3,542.7	99	351.5	799.3	6.0	805.3
1989	3,577.8	73	261.6	822.6	6.0	828.6
1990	3,606.8	51	182.2	828.1	6.0	834.1
1991	3,621.1	33	120.9	817.9	6.0	823.9
1992	3,650.5	22	78.7	796.9	6.0	802.9
1993	3,663.0	14	50.8	769.0	6.0	775.0
1994	3,687.4	9	33.0	737.2	6.0	743.2
1995	3,712.5	6	21.6	703.1	6.0	709.1
1996	3,750.4	4	14.2	670.4	6.0	676.4
1997	3,785.5	2	9.4	636.9	6.0	642.9
1998	3,795.6	2	6.2	602.9	6.0	608.9
1999	3,835.0	1	4.2	568.9	6.0	574.9
2000	3,860.1	1	2.8	535.1	6.0	541.1

SOURCE: Canadian Energy Research Institute.

TABLE E.21

PERU
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	1,009.9	73	73.9	169.7	0.0	169.7
1988	934.0	73	67.9	166.8	0.0	166.8
1989	953.9	72	68.8	167.1	0.0	167.1
1990	974.3	71	69.4	167.7	0.0	167.7
1991	982.9	70	68.9	168.4	0.0	168.4
1992	1,004.8	69	69.2	169.3	0.0	169.3
1993	1,012.4	67	68.2	170.0	0.0	170.0
1994	1,031.1	66	67.7	170.7	0.0	170.7
1995	1,050.2	64	67.0	171.2	0.0	171.2
1996	1,080.2	62	66.7	171.6	0.0	171.6
1997	1,107.9	60	66.0	171.9	0.0	171.9
1998	1,115.2	57	63.7	171.8	0.0	171.8
1999	1,146.7	55	62.7	171.4	0.0	171.4
2000	1,166.8	52	60.8	170.6	0.0	170.6

SOURCE: Canadian Energy Research Institute.

TABLE E.22

TRINIDAD
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	758.4	108	81.7	169.8	0.0	169.8
1988	741.0	107	79.3	172.2	0.0	172.2
1989	757.0	106	80.3	177.4	0.0	177.4
1990	770.1	105	80.7	182.3	0.0	182.3
1991	776.7	103	80.2	186.7	0.0	186.7
1992	790.0	101	80.2	190.5	0.0	190.5
1993	795.7	99	79.1	193.6	0.0	193.6
1994	806.8	97	78.4	196.3	0.0	196.3
1995	818.1	95	77.4	198.3	0.0	198.3
1996	835.4	92	76.8	200.0	0.0	200.0
1997	851.3	89	75.7	201.1	0.0	201.1
1998	855.9	86	73.4	201.6	0.0	201.6
1999	873.8	83	72.1	201.7	0.0	201.7
2000	885.2	79	70.0	201.1	0.0	201.1

SOURCE: Canadian Energy Research Institute.

TABLE E.23

UNITED STATES
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	194,324.5	10	1,898.3	8,478.1	1,568.0	10,046.1
1988	179,663.9	10	1,715.7	8,232.3	1,536.6	9,769.0
1989	193,091.3	9	1,797.8	8,034.5	1,505.9	9,540.4
1990	204,189.5	9	1,848.7	7,867.5	1,475.8	9,343.3
1991	209,670.1	9	1,842.0	7,714.3	1,446.3	9,160.6
1992	220,905.4	8	1,877.5	7,585.3	1,417.3	9,002.8
1993	225,700.9	8	1,851.2	7,458.4	1,389.0	8,847.4
1994	235,017.9	8	1,854.4	7,342.8	1,361.2	8,704.1
1995	244,609.0	8	1,850.2	7,265.3	1,334.0	8,599.3
1996	259,132.5	7	1,870.6	7,197.9	1,307.3	8,505.2
1997	272,560.0	7	1,868.5	7,148.9	1,281.2	8,430.1
1998	276,396.4	6	1,792.8	7,091.1	1,255.5	8,346.7
1999	291, 468.1	6	1,779.5	7,044.8	1,230.4	8,275.2
2000	301,059.1	6	1,721.1	6,994.6	1,205.8	8,200.5

SOURCE: Canadian Energy Research Institute.

TABLE E.24

WESTERN EUROPE
DETAILED REGIONAL SUPPLY FORECAST
1987-2000

Year	Drilling Activity (Mft)	Finding Rate (b/ft)	Reserve Additions (MMb)	Actual Crude Oil Production (Mb/d)	NGL Production (Mb/d)	Total Liquids Production (Mb/d)
1987	4,026.1	32	130.2	494.3	37.6	531.9
1988	3,778.9	31	116.3	530.5	37.2	567.7
1989	4,005.3	29	117.2	543.9	36.9	580.7
1990	4,192.4	28	115.9	552.9	36.5	589.5
1991	4,284.8	26	111.3	604.8	36.1	640.9
1992	4,474.3	24	108.7	601.5	35.8	637.3
1993	4,555.1	23	102.8	595.5	35.4	630.9
1994	4,712.2	21	98.4	599.7	35.1	634.8
1995	4,873.9	19	93.6	582.3	34.7	617.0
1996	5,118.8	18	89.7	565.9	34.4	600.2
1997	5,345.2	16	85.1	549.2	34.0	583.2
1998	5,409.9	14	77.6	532.0	33.7	565.7
1999	5,664.1	13	72.8	514.2	33.3	547.6
2000	5,825.8	11	66.6	495.8	33.0	528.8

SOURCE: Canadian Energy Research Institute.

APPENDIX F

DETAILED SENSITIVITY CASE RESULTS

F1 COMPETITIVE MARKET SCENARIO

TABLE F1.1

COMPETITIVE MARKET SCENARIO
WORLD OIL MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S)	World Demand (MMb/d)	World Supply (MMb/d)	Non CPE Demand (MMb/d)	Non CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.63	62.12	61.54	48.67	45.85	2.24
1988	17.50	63.26	62.97	49.62	47.16	2.17
1989	11.18	66.19	66.20	52.38	50.19	2.20
1990	9.85	69.29	69.10	55.29	52.88	2.22
1991	9.00	72.41	72.21	58.22	55.90	2.12
1992	9.62	74.80	74.60	60.40	58.40	1.81
1993	12.01	75.61	75.61	61.02	59.52	1.50
1994	12.66	76.33	76.32	61.51	60.20	1.30
1995	13.35	77.01	77.00	61.94	60.84	1.10
1996	13.88	77.72	77.72	62.41	61.51	0.90
1997	14.46	78.44	78.43	62.89	62.19	0.70
1998	14.99	79.18	79.19	63.40	62.91	0.50
1999	15.76	79.87	79.87	63.85	63.60	0.25
2000	16.41	80.57	80.56	64.31	64.30	0.00

SOURCE: Canadian Energy Research Institute.

TABLE F1.2

COMPETITIVE MARKET SCENARIO
WORLD CRUDE OIL PRODUCTION SUMMARY
(Mb/d)

		OPEC			NON-OPEC		
Year	Total	Crude Oil	NGLs	CPE	Crude Oil	NGLs	Total NON-OPEC Liquids Production
1987	61,540	17,700	1,408	15,695	22,825	2,811	25,636
1988	62,969	18,800	1,443	15,810	23,017	2,798	25,815
1989	66,199	22,702	1,479	16,010	22,121	2,785	24,907
1990	69,098	26,213	1,516	16,220	21,274	2,774	24,049
1991	72,207	30,005	1,554	16,310	20,473	2,764	23,238
1992	74,603	32,485	1,593	16,200	20,469	2,755	23,225
1993	75,611	33,365	1,633	16,090	20,674	2,747	23,422
1994	76,319	34,365	1,675	16,120	20,319	2,740	23,059
1995	77,004	35,365	1,718	16,160	19,927	2,733	22,661
1996	77,723	36,365	1,762	16,210	19,558	2,728	22,286
1997	78,427	37,365	1,807	16,240	19,191	2,723	21,915
1998	79,187	38,365	1,854	16,280	18,867	2,720	21,588
1999	79,865	39,365	1,903	16,270	18,509	2,717	21,227
2000	80,564	40,365	1,952	16,260	18,170	2,716	20,886

SOURCE: Canadian Energy Research Institute.

TABLE F1.3
COMPETITIVE MARKET SCENARIO
WORLD OIL DEMAND BY PRODUCT
(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,393	20,216	11,817	13,697	62,124
1988	16,762	20,586	12,088	13,823	63,260
1989	17,407	21,686	12,992	14,107	66,191
1990	18,095	22,841	13,914	14,438	69,290
1991	18,817	23,992	14,800	14,806	72,414
1992	19,458	24,848	15,338	15,152	74,797
1993	19,893	25,095	15,214	15,409	75,611
1994	20,288	25,273	15,109	15,661	76,329
1995	20,663	25,409	15,017	15,918	77,008
1996	21,035	25,545	14,962	16,182	77,724
1997	21,396	25,670	14,920	16,448	78,436
1998	21,757	25,803	14,900	16,722	79,182
1999	22,105	25,906	14,863	16,998	79,871
2000	22,450	26,009	14,836	17,276	80,572

SOURCE: Canadian Energy Research Institute.

TABLE F1.4

COMPETITIVE MARKET SCENARIO WORLD OIL DEMAND BY REGION

(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECO	Lesser Developed Countries	OPEC	Centrally Planned Economies	Total World
1987	1,500	16,532	12,198	5,066	9,628	3,744	13,455	62,124
1988	1,505	16,878	12,423	5,118	9,876	3,816	13,644	63,260
1989	1,567	17,765	13,208	5,397	10,476	3,966	13,811	66,191
1990	1,636	18,665	14,001	5,696	11,153	4,138	14,002	69,290
1991	1,707	19,568	14,751	5,992	11,876	4,325	14,193	72,414
1992	1,757	20,208	15,225	6,197	12,506	4,509	14,394	74,797
1993	1,763	20,329	15,182	6,211	12,877	4,654	14,595	75,611
1994	1,766	20,401	15,120	6,212	13,209	4,800	14,820	76,329
1995	1,769	20,458	15,044	6,211	13,509	4,953	15,065	77,008
1996	1,772	20,536	14,987	6,210	13,798	5,110	15,311	77,724
1997	1,777	20,616	14,935	6,216	14,075	5,274	15,544	78,436
1998	1,782	20,708	14,894	6,228	14,348	5,443	15,780	79,182
1999	1,785	20,780	14,835	6,235	14,599	5,615	16,021	79,871
2000	1,790	20,857	14,780	6,247	14,844	5,793	16,260	80,572

SOURCE: Canadian Energy Research Institute.

F2 OPEC MARKET MANIPULATION SCENARIO

TABLE F2.1

OPEC MARKET MANIPULATION SCENARIO
WORLD OIL MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S)	World Demand (MMb/d)	World Supply (MMb/d)	Non CPE Demand (MMb/d)	Non CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.69	62.10	61.53	48.65	45.83	2.24
1988	17.50	63.24	62.94	49.60	47.13	2.17
1989	10.01	66.54	66.54	52.72	50.53	2.20
1990	10.01	69.36	69.36	55.36	53.14	2.22
1991	10.01	71.84	71.84	57.65	55.53	2.12
1992	10.01	74.07	74.07	59.67	57.87	1.81
1993	30.01	65.33	65.33	50.74	49.24	1.50
1994	30.01	61.23	61.23	46.41	45.11	1.30
1995	10.01	62.20	62.20	47.14	46.04	1.10
1996	10.01	63.24	63.24	47.93	47.03	0.90
1997	10.01	64.33	64.33	48.79	48.09	0.70
1998	10.01	65.48	65.48	49.70	49.20	0.50
1999	30.01	59.67	59.67	43.65	43.40	0.25
2000	30.01	56.78	56.78	40.52	40.52	0.00

SOURCE: Canadian Energy Research Institute.

TABLE F2.2

OPEC MARKET MANIPULATION SCENARIO
WORLD CRUDE OIL PRODUCTION SUMMARY
(Mb/d)

		OPEC			NON-OPEC		
Year	Total	Crude Oil	NGLs	CPE	Crude Oil	NGLs	Total NON-OPEC Liquids Production
1987	61,528	17,683	1,408	15,695	22,829	2,811	25,640
1988	62,943	18,771	1,443	15,810	23,021	2,798	25,819
1989	66,535	23,680	1,479	16,010	22,480	2,785	24,266
1990	69,358	26,510	1,516	16,220	21,236	2,774	24,011
1991	71,839	29,170	1,554	16,310	20,939	2,764	23,703
1992	74,068	31,860	1,593	16,200	20,559	2,755	23,314
1993	65,330	21,589	1,633	16,090	22,169	2,747	24,917
1994	61,230	17,065	1,675	16,120	22,530	2,740	25,270
1995	62,203	19,818	1,718	16,160	20,673	2,733	23,406
1996	63,243	21,430	1,762	16,210	20,012	2,728	22,740
1997	64,329	23,127	1,807	16,240	19,330	2,723	22,054
1998	65,479	24,868	1,854	16,280	18,655	2,720	21,375
1999	59,674	17,634	1,903	16,270	20,048	2,717	22,766
2000	56,775	14,611	1,952	16,260	20,134	2,716	22,850

SOURCE: Canadian Energy Research Institute.

TABLE F2.3

OPEC MARKETMANIPULATION SCENARIO
WORLD OIL DEMAND BY PRODUCT
(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,390	20,208	11,810	13,696	62,103
1988	16,761	20,580	12,083	13,823	63,244
1989	17,462	21,824	13,117	14,135	66,536
1990	18,116	22,873	13,915	14,452	69,358
1991	18,750	23,775	14,533	14,781	71,839
1992	19,361	24,565	15,026	15,116	74,068
1993	18,486	21,156	10,962	14,728	65,330
1994	17,896	19,270	9,574	14,490	61,231
1995	18,221	19,639	9,766	14,579	62,203
1996	18,575	20,006	9,947	14,716	63,243
1997	18,951	20,371	10,120	14,890	64,330
1998	19,348	20,740	10,292	15,097	65,479
1999	18,341	17,979	8,376	14,977	59,674
2000	17,671	16,470	7,692	14,944	56,775

SOURCE: Canadian Energy Research Institute.

TABLE F2.4

OPEC MARKET MANIPULATION SCENARIO
WORLD OIL DEMAND BY REGION
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECO	Lesser Developed Countries	OPEC	Centrally Planned Economies	Total World
1987	1,500	16,526	12,192	5,063	9,624	3,743	13,455	62,103
1988	1,505	16,871	12,417	5,115	9,875	3,817	13,644	63,244
1989	1,580	17,875	13,311	5,437	10,538	3,984	13,811	66,536
1990	1,643	18,684	14,008	5,699	11,171	4,151	14,002	69,358
1991	1,695	19,379	14,553	5,919	11,778	4,321	14,193	71,839
1992	1,741	19,974	14,989	6,105	12,365	4,499	14,394	74,068
1993	1,479	17,034	11,906	4,985	11,012	4,320	14,595	65,330
1994	1,352	15,595	10,564	4,498	10,176	4,225	14,820	61,231
1995	1,362	15,779	10,741	4,545	10,336	4,375	15,065	62,203
1996	1,375	15,986	10,907	4,596	10,531	4,536	15,311	63,243
1997	1,390	16,210	11,064	4,654	10,757	4,710	15,544	64,330
1998	1,409	16,450	11,218	4,717	11,012	4,894	15,780	65,479
1999	1,244	14,482	9,409	4,082	9,728	4,708	16,021	59,674
2000	1,160	13,458	8,549	3,800	8,937	4,612	16,260	56,775

SOURCE: Canadian Energy Research Institute.

F3 HIGH RESOURCE SCENARIO

TABLE F3.1

HIGH RESOURCE SCENARIO
WORLD OIL MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S)	World Demand (MMb/d)	World Supply (MMb/d)	Non CPE Demand (MMb/d)	Non CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.10	62.28	61.72	48.83	46.02	2.24
1988	16.83	63.58	63.29	49.94	47.48	2.17
1989	17.26	64.62	64.62	50.81	48.61	2.20
1990	17.70	65.55	65.54	51.55	49.32	2.22
1991	18.12	66.43	66.42	52.24	50.11	2.12
1992	18.68	67.25	67.25	52.86	51.05	1.81
1993	18.80	68.15	68.14	53.56	52.05	1.50
1994	19.50	68.95	68.94	54.13	52.82	1.30
1995	19.71	69.86	69.86	54.80	53.70	1.10
1996	20.31	70.75	70.74	55.44	54.53	0.90
1997	20.97	71.59	71.63	56.05	55.39	0.70
1998	20.81	72.65	72.66	56.87	56.38	0.50
1999	21.53	73.63	73.62	57.61	57.35	0.25
2000	22.36	74.53	74.52	58.27	58.26	0.00

SOURCE: Canadian Energy Research Institute.

TABLE F3.2

HIGH RESOURCE SCENARIO
WORLD CRUDE OIL PRODUCTION SUMMARY
(Mb/d)

Year	Total	OPEC		CPE	NON-OPEC		Total NON-OPEC Liquids Production
		Crude Oil	NGLs		Crude Oil	NGLs	
1987	61,715	17,700	1,408	15,695	23,000	2,811	25,811
1988	63,285	18,800	1,443	15,810	23,334	2,798	26,132
1989	64,618	19,300	1,479	16,010	23,943	2,785	26,729
1990	65,538	19,450	1,516	16,220	24,477	2,774	27,252
1991	66,424	19,800	1,554	16,310	24,895	2,764	27,659
1992	67,245	20,400	1,593	16,200	25,196	2,755	27,952
1993	68,144	21,300	1,633	16,090	25,273	2,747	28,020
1994	68,940	22,000	1,675	16,120	25,304	2,740	28,044
1995	69,858	22,800	1,718	16,160	25,346	2,733	28,080
1996	70,741	23,600	1,762	16,210	25,340	2,728	28,069
1997	71,625	24,400	1,807	16,240	25,354	2,723	28,078
1998	72,660	25,400	1,854	16,280	25,304	2,720	28,025
1999	73,620	26,400	1,903	16,270	25,229	2,717	27,947
2000	74,519	27,400	1,952	16,260	25,090	2,716	27,807

SOURCE: Canadian Energy Research Institute.

TABLE F3.3

HIGH RESOURCE SCENARIO WORLD OIL DEMAND BY PRODUCT (Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,418	20,281	11,873	13,708	62,282
1988	16,815	20,718	12,199	13,848	63,580
1989	17,169	21,051	12,409	13,995	64,624
1990	17,502	21,327	12,556	14,163	65,548
1991	17,839	21,574	12,667	14,355	66,433
1992	18,165	21,785	12,743	14,560	67,254
1993	18,500	22,023	12,847	14,782	68,152
1994	18,813	22,214	12,912	15,008	68,948
1995	19,150	22,442	13,012	15,259	69,861
1996	19,488	22,651	13,092	15,517	70,750
1997	19,821	22,837	13,153	15,778	71,589
1998	20,194	23,107	13,285	16,064	72,651
1999	20,558	23,338	13,380	16,354	73,629
2000	20,911	23,531	13,444	16,643	74,528

SOURCE: Canadian Energy Research Institute.

TABLE F3.4

HIGH RESOURCE SCENARIO
WORLD OIL DEMAND BY REGION
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECO	Lesser Developed Countries	OPEC	Centrally Planned Economies	Total World
1987	1,505	16,582	12,248	5,086	9,656	3,750	13,455	62,282
1988	1,513	16,978	12,520	5,157	9,935	3,833	13,644	63,580
1989	1,521	17,260	12,701	5,212	10,207	3,911	13,811	64,624
1990	1,530	17,462	12,822	5,262	10,473	3,998	14,002	65,548
1991	1,540	17,652	12,907	5,312	10,735	4,094	14,193	66,433
1992	1,549	17,806	12,958	5,356	10,990	4,201	14,394	67,254
1993	1,561	17,976	13,029	5,409	11,262	4,320	14,595	68,152
1994	1,570	18,093	13,057	5,445	11,519	4,445	14,820	68,948
1995	1,583	18,244	13,108	5,489	11,791	4,582	15,065	69,861
1996	1,594	18,392	13,143	5,525	12,057	4,729	15,311	70,750
1997	1,605	18,528	13,161	5,556	12,315	4,881	15,544	71,589
1998	1,620	18,732	13,241	5,610	12,615	5,052	15,780	72,651
1999	1,634	18,907	13,287	5,656	12,900	5,224	16,021	73,629
2000	1,647	19,056	13,306	5,694	13,166	5,399	16,260	74,528

SOURCE: Canadian Energy Research Institute.

F4 U.S. IMPORT FEE SCENARIO

TABLE F4.1

U.S. IMPORT FEE SCENARIO
WORLD OIL MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S.)	World Demand (MMb/d)	World Supply (MMb/d)	Non CPE Demand (MMb/d)	Non CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.63	62.12	61.54	48.67	45.85	2.24
1988	17.50	63.26	62.97	49.62	47.16	2.17
1989	13.89	64.18	64.18	50.37	48.17	2.20
1990	15.06	64.92	64.91	50.92	48.69	2.22
1991	15.97	65.61	67.60	51.41	49.29	2.12
1992	17.14	66.18	66.17	51.79	49.97	1.81
1993	17.69	66.82	66.81	52.22	50.72	1.50
1994	19.13	67.31	67.30	52.49	51.18	1.30
1995	19.82	67.92	67.91	52.86	51.75	1.10
1996	21.21	68.47	68.46	53.16	52.25	0.90
1997	22.63	68.97	69.01	53.43	52.77	0.70
1998	22.69	69.72	69.71	53.94	53.43	0.50
1999	24.46	70.33	70.33	54.31	54.06	0.25
2000	26.25	70.87	70.88	54.61	54.62	0.00

SOURCE: Canadian Energy Research Institute.

TABLE F4.2

U.S. IMPORT FEE SCENARIO
WORLD CRUDE OIL PRODUCTION SUMMARY
(Mb/d)

Year	Total	OPEC		CPE	NON-OPEC		Total NON-OPEC Liquids Production
		Crude Oil	NGLs		Crude Oil	NGLs	
1987	61,540	17,700	1,408	15,695	22,825	2,811	25,636
1988	62,969	18,800	1,443	15,810	23,017	2,798	25,815
1989	64,184	19,300	1,479	16,010	23,509	2,785	26,295
1990	64,913	19,450	1,516	16,220	23,852	2,774	26,627
1991	65,598	19,800	1,554	16,310	24,069	2,764	26,834
1992	66,172	20,400	1,593	16,200	24,123	2,755	26,879
1993	66,806	21,300	1,633	16,090	23,935	2,747	26,683
1994	67,303	22,000	1,675	16,120	23,667	2,740	26,407
1995	67,913	22,800	1,718	16,160	23,401	2,733	26,134
1996	68,463	23,600	1,762	16,210	23,062	2,728	25,791
1997	69,008	24,400	1,807	16,240	22,737	2,723	25,461
1998	69,711	25,400	1,854	16,280	22,356	2,720	25,076
1999	70,325	26,400	1,903	16,270	21,934	2,717	24,652
2000	70,878	27,400	1,952	16,260	21,449	2,716	24,166

SOURCE: Canadian Energy Research Institute.

TABLE F4.3

U.S. IMPORT FEE SCENARIO
WORLD OIL DEMAND BY PRODUCT
(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,393	20,216	11,817	13,697	62,124
1988	16,762	20,586	12,088	13,823	63,260
1989	16,953	20,877	12,366	13,983	64,176
1990	17,152	21,097	12,522	14,151	64,922
1991	17,379	21,283	12,608	14,335	65,606
1992	17,615	21,415	12,625	14,525	66,180
1993	17,868	21,563	12,657	14,728	66,815
1994	18,115	21,644	12,626	14,927	67,312
1995	18,390	21,756	12,631	15,146	67,923
1996	18,671	21,832	12,601	15,367	68,472
1997	18,954	21,881	12,553	15,588	68,974
1998	19,271	22,021	12,591	15,835	69,720
1999	19,580	22,100	12,574	16,079	70,335
2000	19,885	22,142	12,528	16,319	70,873

SOURCE: Canadian Energy Research Institute.

TABLE F4.4

U.S. IMPORT FEE SCENARIO
WORLD OIL DEMAND BY REGION
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECO	Lesser Developed Countries	OPEC	Centrally Planned Economies	Total World
1987	1,500	16,532	12,198	5,066	9,628	3,744	13,455	62,124
1988	1,505	16,878	12,423	5,118	9,876	3,816	13,644	63,260
1989	1,543	16,297	12,954	5,303	10,334	3,934	13,811	64,176
1990	1,566	15,957	13,233	5,412	10,710	4,042	14,002	64,922
1991	1,582	15,802	13,368	5,480	11,033	4,148	14,193	65,606
1992	1,589	15,753	13,379	5,511	11,298	4,256	14,394	66,180
1993	1,594	15,777	13,382	5,540	11,555	4,373	14,595	66,815
1994	1,592	15,846	13,287	5,532	11,750	4,485	14,820	67,312
1995	1,593	15,967	13,213	5,531	11,947	4,607	15,065	67,923
1996	1,591	16,134	13,093	5,511	12,105	4,726	15,311	68,472
1997	1,587	16,331	12,949	5,484	12,233	4,846	15,544	68,974
1998	1,592	16,554	12,901	5,493	12,415	4,985	15,780	69,720
1999	1,591	16,797	12,783	5,480	12,545	5,118	16,021	70,335
2000	1,587	17,057	12,629	5,456	12,640	5,244	16,260	70,873

SOURCE: Canadian Energy Research Institute.

F5 OECD RECESSION SCENARIO

TABLE F5.1

OECD RECESSION SCENARIO
WORLD OIL MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S)	World Demand (MMb/d)	World Supply (MMb/d)	Non CPE Demand (MMb/d)	Non CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.71	62.10	61.52	48.65	45.82	2.24
1988	17.59	63.22	62.93	49.58	47.12	2.17
1989	18.44	63.93	63.93	50.12	47.92	2.20
1990	19.02	64.48	64.47	50.47	48.25	2.22
1991	19.59	65.04	65.04	50.85	48.73	2.12
1992	20.28	65.60	65.59	51.20	49.39	1.81
1993	20.62	66.23	66.22	51.63	50.13	1.50
1994	21.58	66.76	66.79	51.94	50.67	1.30
1995	21.89	67.45	67.44	52.38	51.28	1.10
1996	22.90	68.07	68.06	52.76	51.85	0.90
1997	24.06	68.60	68.61	53.05	52.37	0.70
1998	24.22	69.33	69.32	53.55	53.04	0.50
1999	25.39	69.97	69.96	53.95	53.69	0.25
2000	26.38	70.60	70.65	54.34	54.39	0.00

SOURCE: Canadian Energy Research Institute.

TABLE F5.2

OECD RECESSION SCENARIO
WORLD CRUDE OIL PRODUCTION SUMMARY
(Mb/d)

Year	Total	OPEC		CPE	NON-OPEC		Total NON-OPEC Liquids Production
		Crude Oil	NGLs		Crude Oil	NGLs	
1987	61,519	17,700	1,408	15,695	22,804	2,811	26,615
1988	62,929	18,800	1,443	15,810	22,977	2,798	25,775
1989	63,926	19,300	1,479	16,010	23,250	2,785	26,036
1990	64,472	19,450	1,516	16,220	23,410	2,774	26,185
1991	65,035	19,800	1,554	16,310	23,506	2,764	26,271
1992	65,588	20,400	1,593	16,200	23,539	2,755	26,294
1993	66,218	21,300	1,633	16,090	23,347	2,747	26,094
1994	66,793	22,000	1,675	16,120	23,158	2,740	25,898
1995	67,442	22,800	1,718	16,160	22,930	2,733	25,663
1996	68,060	23,600	1,762	16,210	22,660	2,728	25,388
1997	68,606	24,400	1,807	16,240	22,334	2,723	25,058
1998	69,316	25,400	1,854	16,280	21,961	2,720	24,681
1999	69.960	26,400	1,903	16,270	21,570	2,717	24,287
2000	70,645	27,400	1,952	16,260	21,216	2,716	23,932

SOURCE: Canadian Energy Research Institute.

TABLE F5.3

OECD RECESSION SCENARIO
WORLD OIL DEMAND BY PRODUCT
(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,390	20,208	11,810	13,696	62,101
1988	16,755	20,569	12,073	13,821	63,220
1989	17,033	20,777	12,193	13,926	63,928
1990	17,263	20,921	12,262	14,030	64,476
1991	17,508	21,057	12,311	14,168	65,044
1992	17,752	21,176	12,340	14,327	65,595
1993	18,008	21,321	12,390	14,505	66,226
1994	18,247	21,420	12,403	14,689	66,759
1995	18,518	21,570	12,460	14,902	67,449
1996	18,784	21,682	12,483	15,121	68,069
1997	19,035	21,751	12,471	15,340	68,598
1998	19,323	21,895	12,525	15,584	69,326
1999	19,598	21,997	12,544	15,831	69,969
2000	19,872	22,091	12,599	16,083	70,603

SOURCE: Canadian Energy Research Institute.

TABLE F5.4

OECD RECESSION SCENARIO
WORLD OIL DEMAND BY REGION
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECO	Lesser Developed Countries	OPEC	Centrally Planned Economies	Total World
1987	1,500	16,525	12,191	5,063	9,624	3,743	13,455	62,101
1988	1,505	16,863	12,409	5,112	9,871	3,816	13,644	63,220
1989	1,501	17,035	12,483	5,124	10,094	3,880	13,811	63,928
1990	1,493	17,110	12,486	5,121	10,312	3,953	14,002	64,476
1991	1,490	17,192	12,477	5,126	10,529	4,037	14,193	65,044
1992	1,489	17,256	12,449	5,134	10,740	4,132	14,394	65,595
1993	1,491	17,337	12,445	5,153	10,965	4,240	14,595	66,266
1994	1,489	17,372	12,404	5,155	11,168	4,351	14,820	68,759
1995	1,494	17,452	12,398	5,173	11,392	4,476	15,065	67,449
1996	1,498	17,514	12,364	5,178	11,597	4,606	15,311	68,069
1997	1,501	17,553	12,302	5,177	11,783	4,739	15,544	68,598
1998	1,508	17,656	12,298	5,198	12,000	4,886	15,780	69,326
1999	1,514	17,730	12,262	5,212	12,197	5,033	16,021	69,969
2000	1,522	17,802	12,219	5,225	12,388	5,187	16,260	70,603

SOURCE: Canadian Energy Research Institute.

F6 HIGH LDC GROWTH SCENARIO

TABLE F6.1

HIGH LDC GROWTH SCENARIO
WORLD OIL MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S)	World Demand (MMb/d)	World Supply (MMb/d)	Non CPE Demand (MMb/d)	Non CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.77	62.11	61.52	48.65	45.83	2.24
1988	17.73	63.23	62.94	49.59	47.13	21.7
1989	18.90	63.97	63.96	50.15	47.95	2.20
1990	19.85	64.56	64.55	50.56	48.33	2.22
1991	20.38	65.22	65.21	51.02	48.90	2.12
1992	21.37	65.80	65.79	51.41	49.59	1.81
1993	21.86	66.47	66.51	51.88	50.42	1.50
1994	22.76	67.12	67.11	52.30	50.99	1.30
1995	23.66	67.79	67.80	52.73	51.64	1.10
1996	24.89	68.42	68.41	53.10	52.20	0.90
1997	26.14	68.99	68.98	53.45	52.74	0.70
1998	26.75	69.72	69.76	53.94	53.48	0.50
1999	27.78	70.46	70.45	54.44	54.18	0.25
2000	29.25	71.13	71.12	54.87	54.86	0.00

SOURCE: Canadian Energy Research Institute.

TABLE F6.2

HIGH LDC GROWTH SCENARIO
WORLD CRUDE OIL PRODUCTION SUMMARY
(Mb/d)

		OPEC			NON-OPEC		
Year	Total	Crude Oil	NGLs	CPE	Crude Oil	NGLs	Total NON-OPEC Liquids Production
1987	61,523	17,700	1,408	15,695	22,808	2,811	25,619
1988	62,941	18,800	1,443	15,810	23,989	2,798	25,787
1989	63,964	19,300	1,479	16,010	23,289	2,785	26,075
1990	64,553	19,450	1,516	16,220	23,492	2,774	26,267
1991	65,209	19,800	1,554	16,310	23,680	2,764	26,445
1992	65,793	20,400	1,593	16,200	23,744	2,755	26,499
1993	66,505	21,300	1,633	16,090	23,634	2,747	26,381
1994	67,108	22,000	1,675	16,120	23,473	2,740	26,213
1995	67,798	22,800	1,718	16,160	23,286	2,733	26,020
1996	68,407	23,600	1,762	16,210	23,006	2,728	25,735
1997	68,982	24,400	1,807	16,240	22,711	2,723	25,435
1998	69,757	25,400	1,854	16,280	22,402	2,720	25,122
1999	70,450	26,400	1,903	16,270	22,059	2,717	24,777
2000	71,123	27,400	1,952	16,260	21,694	2,716	24,410

SOURCE: Canadian Energy Research Institute.

TABLE F6.3

HIGH LDC GROWTH SCENARIO WORLD OIL DEMAND BY PRODUCT

(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,391	20,208	11,810	13,698	62,108
1988	16,758	20,572	12,075	13,827	63,232
1989	17,055	20,779	12,178	13,954	63,966
1990	17,323	20,919	12,218	14,098	64,559
1991	17,605	21,071	12,267	14,272	65,216
1992	17,872	21,187	12,284	14,459	65,800
1993	18,148	21,332	12,330	14,664	66,470
1994	18,412	21,461	12,367	14,878	67,116
1995	18,686	21,592	12,407	15,109	67,792
1996	18,953	21,692	12,423	15,345	68,415
1997	19,211	21,772	12,426	15,584	68,992
1998	19,493	21,906	12,479	15,841	69,716
1999	19,780	22,043	12,528	16,108	70,460
2000	20,055	22,147	12,556	16,375	71,131

SOURCE: Canadian Energy Research Institute.

TABLE F6.4

HIGH LDC GROWTH SCENARIO WORLD OIL DEMAND BY REGION
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECO	Lesser Developed Countries	OPEC	Centrally Planned Economies	Total World
1987	1,499	16,519	12,185	5,061	9,646	3,742	13,455	62,108
1988	1,502	16,842	12,392	5,106	9,932	3,813	13,644	63,232
1989	1,500	17,000	12,459	5,123	10,201	3,872	13,811	63,966
1990	1,497	17,071	12,458	5,132	10,465	3,934	14,002	64,559
1991	1,497	17,159	12,456	5,149	10,752	4,009	14,193	65,216
1992	1,497	17,205	12,416	5,160	11,035	4,093	14,394	65,800
1993	1,500	17,266	12,397	5,179	11,345	4,190	14,595	66,470
1994	1,502	17,299	12,357	5,189	11,658	4,291	14,820	67,116
1995	1,507	17,333	12,308	5,199	11,979	4,402	15,065	67,792
1996	1,510	17,354	12,237	5,196	12,291	4,516	15,311	68,415
1997	1,510	17,364	12,152	5,190	12,598	4,634	15,544	68,992
1998	1,517	17,414	12,106	5,201	12,935	4,763	15,780	69,716
1999	1,521	17,468	12,058	5,214	13,281	4,897	16,021	70,460
2000	1,525	17,498	11,985	5,221	13,612	5,030	16,260	71,131

SOURCE: Canadian Energy Research Institute.

F7 HIGH CPE NET EXPORT SCENARIO

TABLE F7.1

HIGH CPE NET EXPORT SCENARIO
WORLD OIL MARKET SUMMARY
1987-2000

Year	Price ($1987 U.S)	World Demand (MMb/d)	World Supply (MMb/d)	Non CPE Demand (MMb/d)	Non CPE Supply (MMb/d)	Net CPE Exports (MMb/d)
1987	18.63	62.12	61.55	48.67	45.85	2.24
1988	17.50	63.26	62.96	49.61	47.15	2.17
1989	18.54	64.00	64.00	50.19	47.99	2.20
1990	19.40	64.58	64.58	50.58	48.36	2.22
1991	19.82	65.22	65.22	51.03	48.91	2.12
1992	20.69	65.79	65.79	51.40	49.59	1.81
1993	20.72	66.52	66.52	51.93	50.23	1.70
1994	20.77	67.38	67.38	52.56	50.86	1.70
1995	21.52	68.19	68.19	53.13	51.43	1.70
1996	22.53	68.89	68.89	53.58	51.88	1.70
1997	23.27	69.59	69.59	54.04	52.35	1.70
1998	23.48	70.43	70.43	54.65	52.95	1.70
1999	24.06	71.30	71.30	55.28	53.58	1.70
2000	24.91	72.12	72.12	55.86	54.16	1.70

SOURCE: Canadian Energy Research Institute.

TABLE F7.2

HIGH CPE NET EXPORT SCENARIO
WORLD CRUDE OIL PRODUCTION SUMMARY
(Mb/d)

Year	Total	OPEC		CPE	NON-OPEC		Total NON-OPEC Liquids Production
		Crude Oil	NGLs		Crude Oil	NGLs	
1987	61,549	17,708	1,408	15,695	22,825	2,811	25,636
1988	62,958	18,789	1,443	15,810	23,017	2,798	25,815
1989	63,998	19,301	1,479	16,010	23,321	2,785	26,106
1990	64,582	19,450	1,516	16,220	23,520	2,774	26,294
1991	65,224	19,800	1,554	16,310	23,695	2,764	26,460
1992	65,789	20,400	1,593	16,200	23,740	2,755	26,496
1993	66,521	21,161	1,633	16,290	23,589	2,747	26,337
1994	67,383	21,996	1,675	16,520	23,351	2,740	26,092
1995	68,191	22,804	1,718	16,760	23,075	2,733	25,809
1996	68,892	23,580	1,762	17,010	22,711	2,728	25,439
1997	69,586	24,388	1,807	17,240	22,325	2,723	25,049
1998	70,428	25,374	1,854	17,480	21,899	2,720	24,619
1999	71,297	26,405	1,903	17,720	21,450	2,717	24,168
2000	72,119	27,405	1,952	17,960	20,985	2,716	23,701

SOURCE: Canadian Energy Research Institute.

TABLE F7.3

HIGH CPE NET EXPORT SCENARIO WORLD OIL DEMAND BY PRODUCT

(Mb/d)

Year	Gasoline	Middle Distillates	Heavy Fuel Oil	Other	Total Crude Oil
1987	16,393	20,216	11,817	13,697	62,124
1988	16,761	20,585	12,087	13,823	63,258
1989	17,062	20,795	12,195	13,945	63,998
1990	17,332	20,923	12,234	14,083	64,582
1991	17,615	21,081	12,279	14,251	65,225
1992	17,883	21,188	12,289	14,431	65,790
1993	18,173	21,357	12,359	14,635	66,522
1994	18,481	21,574	12,470	14,859	67,384
1995	18,787	21,760	12,547	15,096	68,191
1996	19,080	21,895	12,581	15,335	68,892
1997	19,372	22,023	12,612	15,579	69,586
1998	19,692	22,206	12,689	15,843	70,429
1999	20,020	22,393	12,767	16,117	71,297
2000	20,343	22,558	12,827	16,393	72,120

SOURCE: Canadian Energy Research Institute.

TABLE F7.4

HIGH CPE NET EXPORT SCENARIO
WORLD OIL DEMAND BY REGION
(Mb/d)

Year	Canada	United States	Western Europe	Pacific OECO	Lesser Developed Countries	OPEC	Centrally Planned Economies	Total World
1987	1,500	16,532	12,198	5,066	9,628	3,744	13,455	62,124
1988	1,505	16,877	12,423	5,118	9,875	3,816	13,644	63,258
1989	1,503	17,061	12,512	5,141	10,089	3,879	13,811	63,998
1990	1,503	17,156	12,532	5,155	10,287	3,947	14,002	64,582
1991	1,505	17,273	12,552	5,178	10,496	4,028	14,193	65,225
1992	1,507	17,349	12,534	5,197	10,690	4,118	14,394	65,790
1993	1,516	17,469	12,566	5,235	10,916	4,225	14,595	66,522
1994	1,527	17,614	12,628	5,280	11,169	4,346	14,820	67,384
1995	1,537	17,735	12,656	5,315	11,409	4,605	15,065	68,191
1996	1,543	17,827	12,645	5,333	11,623	4,605	15,311	68,892
1997	1,552	17,923	12,633	5,351	11,842	4,741	15,544	69,586
1998	1,564	18,063	12,662	5,385	12,083	4,892	15,780	70,429
1999	1,578	18,210	12,688	5,421	12,330	5,050	16,021	71,297
2000	1,590	18,339	12,697	5,454	12,567	5,213	16,260	72,120

SOURCE: Canadian Energy Research Institute.

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